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Intelligent and process control of mechatronic systems in object classification

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Abstract

In this paper is presented systematized mechatronic system for classification of objects by color using an artificial vision. For the mechatronic system will be used the stations for distribution and sorting of parts. Control and regulate the process of classifying objects by color, will be done by integration of an artificial vision into a mechatronic system and implemented using control units that are supported by algorithms generating in the programming language Matlab.

Key words: Mechatronic system, Robotic, artificial vision, Vision system, Sensors, Matlab

1. Introduction

For the purposes of this work, it was used: mechatronic station of industrial robot, mechatronic station for the distribution of work pieces, mechatronic station for sorting according to a particular criterion, vision system (camera).

2. Mechatronic station of industrial robot

The modular production system (MPS) is divided into two parts. The first part of the station represents all its components together with its sensors and actuators, which are set according to a particular schedule [1]. The other part of the station consists of comparators, relays, control panel, input-output terminals and control units for which the station is control [2,3]. These components could also be joined by an electro pneumatic converter located at the top of the station for easy connection with pneumatic executive members. The phases of work at this station can include: planning, assembly, programming, commissioning, work, maintenance and identification of an error . Flexible production system FESTO uses the robotic arm Mitsubishi model RV-2AJ as its main resource [4]. The industrial robot model RV-2AJ is presented in Figure 1.

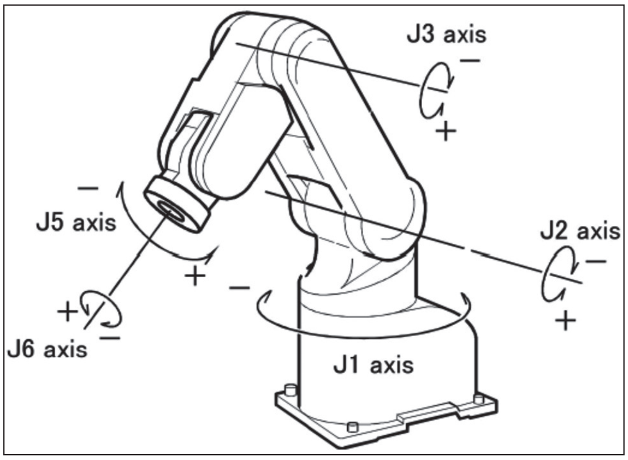


Figure 1. Robot model RV-2AJ

3. Location and selection of vision system

The vision system will be placed on the bracket under which the board will be located where the camera will capture the work pieces, and in the program based on the given algorithms, identify the color. It is selected the simple camera type Gigatech shown in Figure 2, with the following characteristics: Image sensor: CMOS, a premium glass lens, Camera: 12MP, Dynamic resolution: 640 * 480px, frame rate: 30fps.

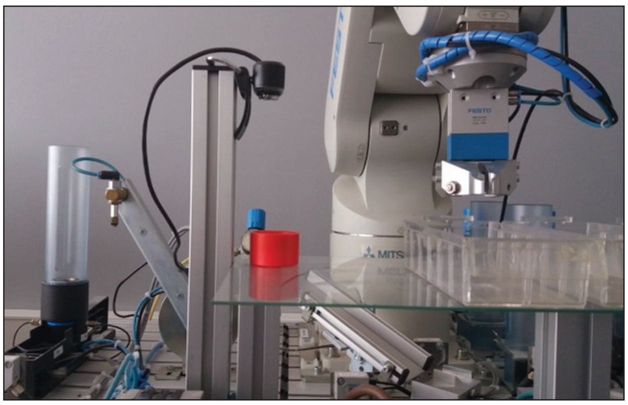


Figure 2. Webcam Location

3.1 Parts that constitute a modular production system

The system manipulates with the parts that having multiple versions. One of them has the shape of a cylinder and can have three different colors: red, blue and green (Figure 3). It is also the basic part that is used through the whole system. The reason why there are several versions of the cylinder is that a particular cylinder when sorting will be sorted into the section it belongs to. The specifics of each cylinder are given in Table 1.

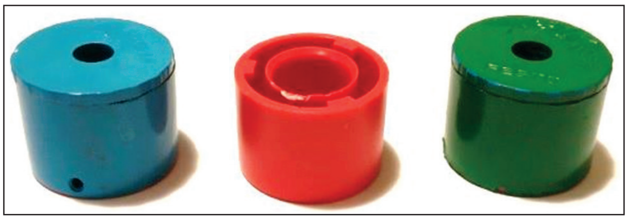


Figure 3. Operating parts (cylinder versions)

Table 1. Basic work piece parameters

Cylinder color	Red	Blue	Green
Material	Plastic	Plastic	Plastic
Height [mm]	23	25	25

3.2 Sorting of parts

To automate the sorting of parts, as a tool for creating a virtual project in the automation of technological processes and production, the CIROS software package will be used. Its flexibility makes it suitable for use in various areas of automation and is also suitable for using real-time simulations.

Experimental research in this paper is done in the Ciros Studio software, in which the Melfa Basic IV language is integrated. Melfa Basic IV is a language that serves us to control the modular production system station and consists of specific commands and databases.

Other software used in this project is Matlab. Matlab is a high-level language and an interactive environment for numerical computing, visualization and programming. Using Matlab, we can analyze data, develop algorithms, and create models and applications. The language, tools and built-in mathematical functions allow us to explore more approaches and achieve a solution faster than spreadsheets or traditional programming languages such as C / C ++ or Java. For this work Matlab is used for image processing and communication with a robot. The camera will be connected to a computer with USB port, and the robot will be connected to the serial connection. Matlab will control these communications with the help of some additional tools that are integrated into this program. In order to start the system, it is necessary to enable communication between robot controllers and computers. Since it is not automatically enabled, it must be done by certain constructions between the computer and the robot.

4. Color detection in Matlab

The criteria for sorting the parts according to the color is explained is explained in this section. It is presented color detection algorithm that will be created in the Matlab programming language, which will be the basis for sorting the parts according to the color criteria. There are many ways to discover the object colors. Color recognition includes the comparison of each pixel from the image and results in the dominant color of the given object, which will be explained below. Diagram for color detection in present in the figure 4.

The **first step** is to load the image. The **second step** is to construct a matrix for red, green and blue color. Here is a bitmap image with different shapes filled with primary colors of red, blue and green. The objects in the picture are separated based on colors. The image is a RGB image that is a three-dimensional matrix.

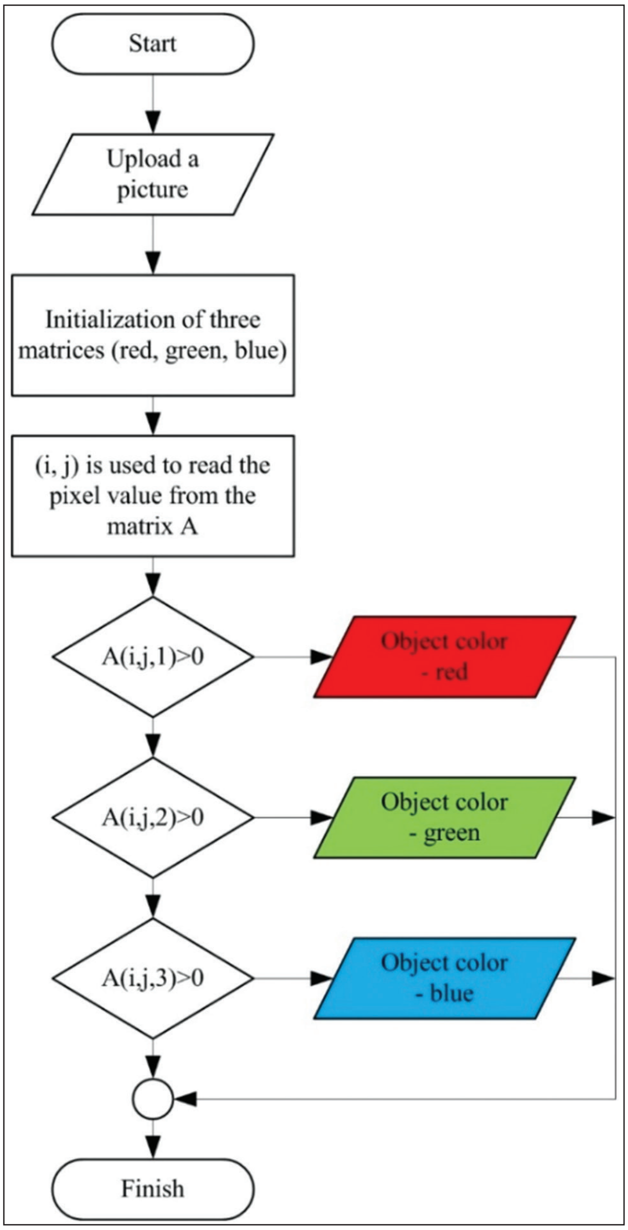
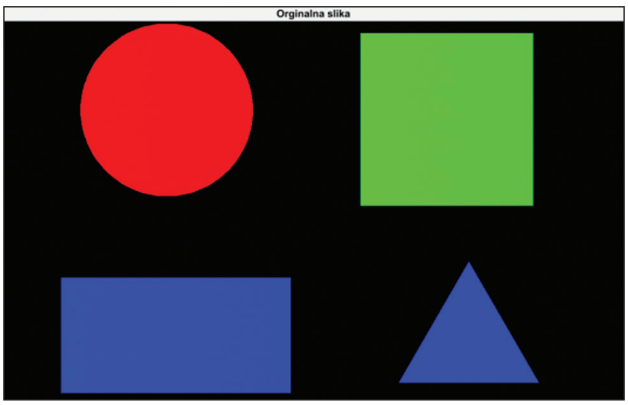
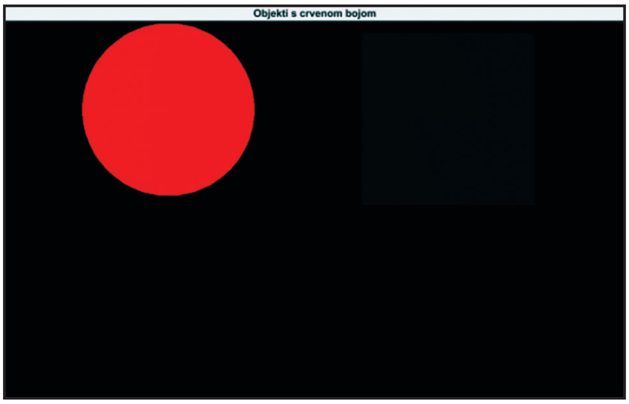


Figure 4. Diagram for color detection



a)



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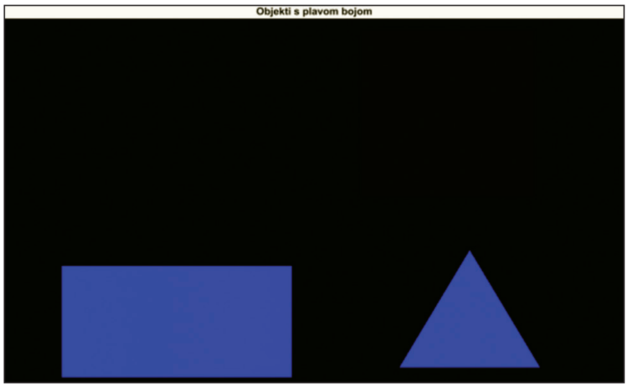
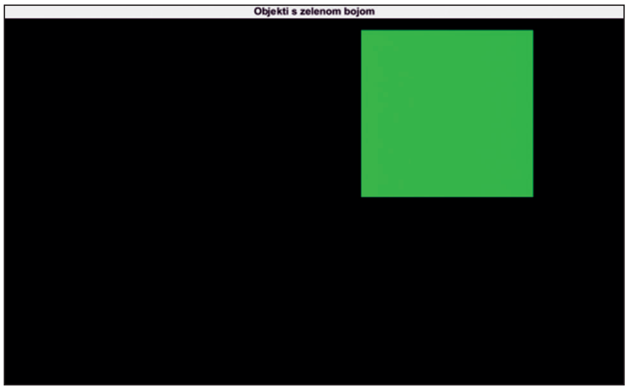


c)



d)

Figure 5. a) Original picture; b) Object with red color; c) Object with blue color; d) Object with green color

The **third step** allows the use of (i, j) to obtain the position of the pixels of the image A. In Figure A (i, j, 1) is the value of the red color, A (i, j, 2) represents the green color and A (i, 3) represents a blue color. All pixels are comparing each other. If the red color matrix has a positive value, and the others are zero, then this object is detected as red. Also, the procedure is repeated for green and blue objects. Each color image is displayed separately. The result is visible on the above images. Color recognition in the programming language Matlab is the basis that is required when sorting parts by color criteria. This part of the experimental research is helpful in the realization of an experiment of sorting the parts according to the color criteria. In the continuation of this work is given a code in Matlab to detect the color of objects.

```
clc;
closeall;
A=imread('Slikacrna1.png');
figure,imshow(A);
title('Orginalnaslika');
% Prelociratimatricuvelicine A
Red=zeros(size(A));
Blue=zeros(size(A));
Green=zeros(size(A));
for i=1:size(A,1)
for j=1:size(A,2)
%Objekti s crvenombojom
if (A(i,j,1) >= 0)
Red(i,j,1)=A(i,j,1);
end
%Objekti s zelenombojom
if(A(i,j,2) >= 0)
Green(i,j,2)=A(i,j,2);
end
%Objekti s plavombojom
if(A(i,j,3) >=  0)
Blue(i,j,3)=A(i,j,3);
end
end
end
Red=uint8(Red);
figure,imshow(Red);
title('Objekti s crvenombojom');
Blue=uint8(Blue);
figure,imshow(Blue);
title('Objekti s plavombojom');
Green=uint8(Green);
figure,imshow(Green);
title('Objekti s zelenombojom');
```

5. Sorting work objects by color

In order to realize the criterion for sorting work pieces by color, an algorithm developed and written in the Matlab program is used, which recognizes the work pieces by color with the Melfa Basic IV software. This two software will interact with each other and as a result it will sort the parts by color. In this section, will be clarified the criterion for classifying work pieces by color, which includes the entire mechatronic system. Figure 6 shows an intelligent mechatronic system consisting of the following components:

1. mechatronic workstations for the distribution of work pieces,
2. mechatronic workstations of industrial robots Mitsubishi RV-2AJ,
3. vision system,
4. a computer with the necessary software,
5. controller for robot station,
6. warehouse with work pieces.

The listed items are shown in the following figure. The figure also shows the procedure for sorting the parts according to the color criteria [5].

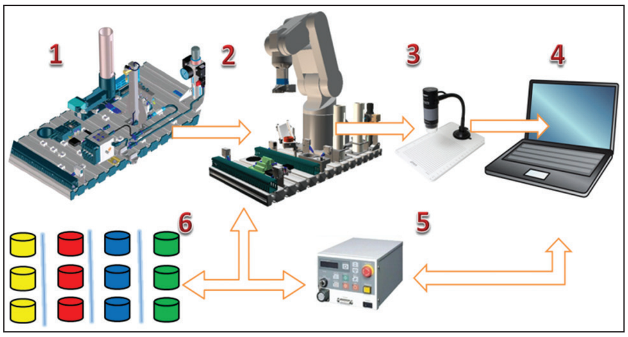


Figure 6. Sorting work objects according to color criteria

The following numbers from 1 to 6 show the stages in the work of sorting the parts according to the color criteria:

1. A mechatronic distribution station distributes pieces using a pneumatic rotary motor and vacuum gripper to a mechatronic station of an industrial robot;
2. The sensor at the industrial robot station sends a signal to the robot that the work piece is present, and the robot distributes it to the vision system;
3. The camera pictures the workpiece and sends it to the computer;
4. The computer processes an image using algorithms generated in the Matlab programming language. According to the

color of the work piece, makes the decision and sends it to the robot controller;
5. The robot controller instructs the robot about the color of the workpiece, and which routine to select and place the work piece in the intended warehouse;
6. At the end of the program cycle, work pieces are sorted according to the color criteria;

Below is presented flowchart for the process of sorting parts according to the color criteria.

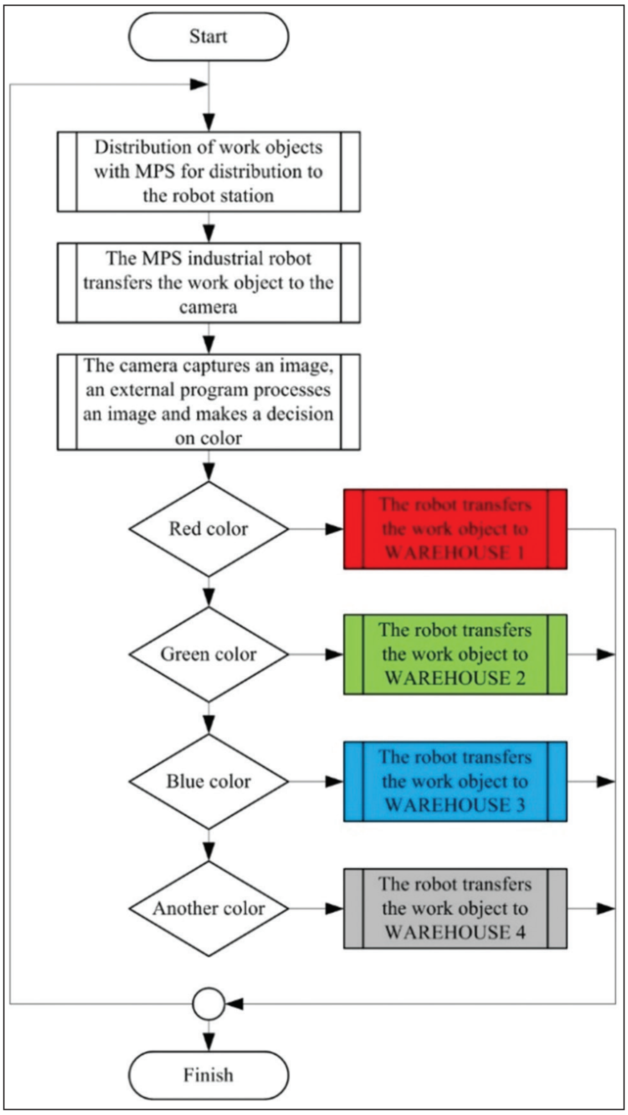


Figure 7. Flowchart for the process of sorting parts according to the color criteria

6. Conclusion

Experimental analysis on real models of mechatronic workstations and the using of the vision sensor achieved results that confirm the synchronization and automation of the process for distribution objects, then the transfer objects by the industrial robot to the vision sensor, and finally sorting according to the color criteria. Integrating the vision sensor into mechatronic systems, has obtained intelligent mechatronic system for control and regulation of production processes.

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Analysis of resource efficiency in the production of industrial steam based on the availability of measurement data

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Abstract

Resource efficiency in production includes the best use of resources used in production. In the production of industrial steam these are: boiler fuel and water therefore they should be used efficiently. In order to increase the resource efficiency in the production of industrial steam, among other things, it is necessary to measure: consumption of boiler water, boiler fuel, steam produced, temperature and composition of combustion products at the exit from the furnace, the temperature of the water from blowdown of boilers, the quality of boiler water and recovery of the condensate from the process. The paper analyzes the resource efficiency in the production of industrial steam, taking into account the influence of the available measurements. Comparison is made for three production facilities in breweries in Bosnia and Herzegovina.

Key words: brewing industry, industrial steam consumption, resource efficiency,

1. Introduction

The main resources in the production of industrial steam are water and boiler fuel. For the purpose of their efficient exploitation, it is necessary to perform measurements related to water and boiler fuel, as well as other parameters which are influencing factors on resource efficiency.

2. The impact of measuring parameters on resource efficiency in the production of industrial steam

Resource efficiency in the production of industrial steam is influenced by: the quality and temperature of boiler fuel, oxygen content (O_2) in flue gases, flue gas temperature, temperature and quality of boiler water, type and cycle of boiling and boiling off of boilers, process condensate recovery, compliance of boiler operation, insulation of pipes, valves, flanges, chimneys and other boiler equipment, etc. [1]. To improve the resource efficiency, the above mentioned parameters should be measured and their values monitored.

2.1 Checking the characteristics of boiler Fuel

The combustion process is influenced by the quality (composition) of boiler fuel. In all three breweries that were the subject of this work, oil is used as boiler fuel, and in one of them the gas additionally.

Oil should be warm and heated enough. For pumping oil from the tank to the burner, the oil temperature should be 50 – 70°C. This temperature should be measured and maintained at the required value. The minimum pressure in the circular line is adjusted in relation to the required temperature of the oil on the burner, which is here approx. 142 °C, at the pressure of approx. 4 bar [2]. This temperature is needed for spraying oil. The temperature of the oil on the burner should be measured and kept at the recommended value for the installed burners.

2.2 Measurement of the characteristics of combustion products at the boiler output

The combustion process in the boiler furnace should be carried out completely and with a certain excess air coefficient. If combustion is incomplete, one part of the chemically bound energy in the fuel is not released, which does not fully utilize the fuel in the combustion process. If more air is fed to the combustion than necessary, then the combustion temperature will be lower, which will make the combustion process more difficult.

It is necessary to provide an optimum air-fuel ratio in the burner, i.e. optimum combustion through feedback on the content of O_2 in flue gases. Higher flue gas temperatures indicate poor heat exchange or other irregularities. Flue gas temperatures below 130 °C can cause corrosive condensation, depending on the sulfur content of the fuel [3]. In order to determine the completeness of the combustion as well as the coefficient of excess air, it is necessary to measure the composition of the products of combustion at the exit from the furnace. Table 1 presents approximate values of the flue gas temperature depending on the pressure in the boiler.

Table 1. Approximate values of flue gas temperatures [3]

Boiler pressure (bar)	Reccomended maximum temperature of flue gas (°C)
2	190
5	210
7	230
10	245

Automatic control of oxygen content involves measuring oxygen content in products of combustion. This improves the quality of combustion and resource efficiency i.e. energy savings are achieved by continuously optimizing excess air, thus continuously guiding the plant to a maximum degree of utility.

Automatic control of oxygen content i.e. by installing sensors for measuring the content of oxygen in flue gases and systems for combustion control, it is possible to save 1 – 2 % of energy, i.e, consumed boiler fuel [4].

Measured emission values should be within the permitted (limit) values prescribed by laws. Figure 1 shows the discharge and measurement of flue gases from the boiler in the operation of one brewery.

Figure 1. Discharge and measurement of flue gases from boiler

2.3 Checking the characteristics of boiler water and condensate

The damages caused by the failure of the boiler plants in large numbers are caused by the inadequate quality of the water supply. There are three methods for removing gases from the water supply [4]:

1. Thermal process - warming up of feed water in the degasser. Gases are separated from the feed water as the water solubility decreases with water temperature increase.
2. Chemical procedure - hydrazine that binds oxygen is added to boiler feed water. This is the best procedure for removal of oxygen from the feed water, because the resulting compounds do not form precipitates.
3. Mechanical procedure - it is possible to remove a certain quantity of gases from feed water by mixing the water or by dispersing it with steam.

Oxygen dissolved in the feed water acts corroding to the heat exchange surfaces of the boiler, and its removal is mainly done by the thermal preparation of water (heating at 105 °C, when there are virtually no gases in the water) or by chemical preparation, when the chemicals that bind oxygen are added in feed water and create non-aggressive compounds with oxygen.

The temperature at which the thermal preparation of water is carried out should be measured and kept at the required value.

In order to provide certain quality of boiler water, it is necessary to measure daily, i.e. perform laboratory control of the following parameters: hardness, alkalinity and pH value from: water softener, condensate reservoir, feed water tank and boilers. Measured values must be within the prescribed limits.

Figure 2. Condensate reservoir

In most processes, the condensate is returned from the process to the condensate reservoir. Figure 2 shows the condensate reservoir used in the process.

Reducing condensate loss or increasing condensate returns is one of the main measures to reduce energy losses in the system for supplying industrial steam for production facilities. According to [2], condensate recovery is 50 – 70 %.

When in the condensate tank the amount of condensate falls below a certain level, then the chemically prepared water from the softener (Figure 3) goes into the condensate reservoir and is mixed it with the condensate.

Figure 3. Double automatic water softener

It is necessary to measure the flow of water from the softener to the condensate tank. If there is a higher return of the condensate from the process, less water from the softener will go to the condensate tank. From the condensate reservoir, the condensate goes into the feed water supply tank with the degasser (Figure 4), in which the thermal preparation of water is carried out (heating at 105 °C).

Figure 4. Feed water reservoir with degasser

2.4 Treatment of water from blowdown and desalting boilers

Blowdown and desalting boilers is an important part of boiler water treatment and its task is to limit the concentration of salt and other undesirable substances in boiler water.

Boiler sludge is removed from the boiler by blowdown. Water foaming in the boiler is due to the high concentration of sodium salts, hydroxides and mechanical admixtures. The consequences of foaming are: increased humidity of the vapor contaminated with impurities from which the foam consists of and the deposition of this impurity in the steam super heaters and shutters causes inaccuracy of the water level in the boiler. By discharging water from the boiler, the concentration of desalting salt in boiler water is regulated, and this process is called of boiler.

The optimum rate of blowdown and desalting boilers is crucial, since excessive blowdown results in heat loss, increase of water consumption and an increase in the amount of chemicals used to treat the feed water, while low blowdown increases the concentration of unwanted substances in boiler water. By draining a certain amount of boiler water, exactly as needed, a significant amount of water, energy and chemicals is saved.

Any discharge of boiling water from the steam boiler increases the consumption of water i.e. requires the supply of a new amount of water and increases the heat loss. The frequency of desalting depends on the conductivity of the boiler water, usually this quantity of water is 5% of the steam performance of the boiler [5]. Heat losses due to the boiler blowdown reach 2% of the fuel cost [1]. The maximum statutory water temperature that flows into the sewer can be 30°C [6], and if the water from blowdown and desalting boilers is released to the sewage, it is necessary to cool it first to the allowed temperature before the discharge.

When discharging water from boiler during blowdown and desalting boilers, the wastewater is discharged from boiler under pressure and temperature. There are three ways to perform these actions: continuous, manual and automatic.

In the case of continuous discharge blowdown and desalting boilers a calibrated valve is used, and the discharge hole is at the lowest point of the boiler (Figure 5).

As the name says, continuous discharging of boiler during blowdown and desalting boilers means continuous discharge of water from the working space of the boiler in a given quantity is carried out. All boilers have a manual discharge valve as mandatory equipment. Manual removal allows the sludge to be removed from the bottom of the boiler.

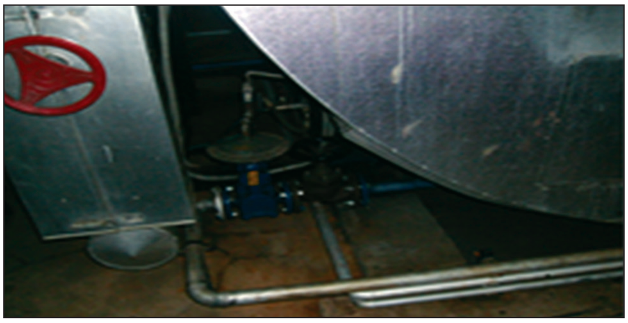

Figure 5. Valve for blowdown boilers

The drainage hole is located in the level of free water surface in the boiler. To control the boiler desalting device, the conductivity of the boiler water is measured by taking the water through the valve for water sampling on the watertight glass (Figure 6).

Figure 6. Valve for water sampling on watertight glass

In automatic blowdown, the automatics independently regulate the controllability of boiler water, which changes due to evaporation (Figure 7).

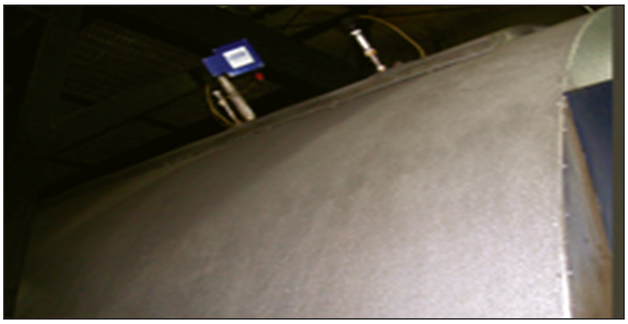

Figure 7. Device for measuring and controlling boiler water conductivity

When the conductivity is increased above a certain conductivity value, previously set in the controller, the drain valve opens (Figure 8) and drains the boiled water enriched with salt. When the conductivity is below the limit value, the drain valve is closed [2].

Figure 8. Valve for desalting boilers

The best results are achieved by automatic blowdown and desalting boilers for the following reasons [4]:

- The need for a permanent presence of a trained boiler operator is reduced,
- Heat losses and the need for the use of chemicals are reduced to a minimum,
- Increased efficiency while the possibility of damage and stagnation is reduced to a minimum.

2.5 Measurement of load and compliance of boiler operation

When there is more than one boiler on site, the load scheduling method saves energy by adjusting (establishing and maintaining) the number of boilers in operation and their load level with the current needs of users in the production process. The efficiency of the combustion process varies depending on the level of the current load (in relation to the installed boiler capacity) and increases if the boiler operates at higher loads (large flame). The load scheduling method maximizes the usefulness level by providing a minimum number of boilers in the operation which operate for a maximum long time and at a higher load level. It is possible to save up to 4% of energy by improving operational procedures and managing the load distribution within the boiler room [4].

When the boiler is loaded near the maximum load, then the second boiler should be switched on. When the steam production is reduced i.e. when the boiler load begins to decrease, the second boiler is switched off and the leading boiler remains in operation.

In order to determine the optimum loading of boilers in operation, i.e. the load at which the best performance and efficiency of boiler utilization is achieved, the steam produced should be measured and determine under which boiler load the smallest amount of boiler fuel is consumed. Therefore, in order to achieve saving of energy and boiler fuel, it is necessary to install gauges for the measurement of produced steam and consumed boiler fuel. In Figure 9, a meter for measuring the steam produced in the boiler is shown.

Figure 9. Measurement of produced steam

The measurement of the produced steam is significant, due to balancing and optimizing the consumption of steam for different consumers in the production facility.

2.6 Analysis of the condition of pipelines and other equipment

The surface of the tube has approximately the same temperature as vapor or condensate. As a result, significant heat losses can occur in the environment from the surface of uninsulated pipes and vessels. The primary objective of isolation in industrial and power plants is to reduce heat losses and to prevent the burnout of people working and using the plants [7]. Therefore, the thermal insulation of all the heated places should be given great attention. Insulation of pipelines and connections is one of the most economical ways of increasing energy efficiency in systems for distribution of energy fluids. Insulation with hot insulation is done on boilers, oil pipes, pipes of steam pipes, hot water pipes, containers, knee insulation, valves, etc.

This type of insulation is made with mineral wool, with a thickness of 30 – 200 mm. The protective linings are made of aluminum sheet, galvanized sheet metal, galvanized colored sheet metal or stainless steel according to the customer's choice.

It is necessary to inspect the insulation regularly and measure the temperature of all heated surfaces. The surface temperature of all insulated tubes, surfaces and other heated elements should be below 60°C. The calculations show that the costs are high if the pipelines are left uninsulated and that significant savings can be obtained with insulation thickness of 25 – 50 mm. Isolation of supports is justified at large pipeline diameters. Most often, the pipelines remain uninsulated for easier maintenance. Figures 10 and 11 show the state of insulation and the measured temperature of the equipment. The visual inspection shows that the insulation is correct, and the measurement of the thermal imaging camera has determined that there are no heat losses and that the measured temperatures on the side of the boiler are 32.7°C and at the steam divider 34.8°C.

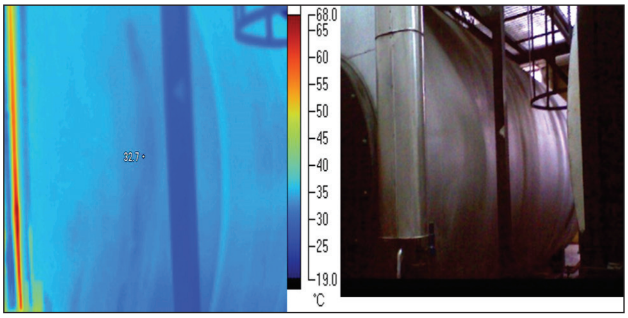

Figure 10. Measured temperature at the side of the boiler

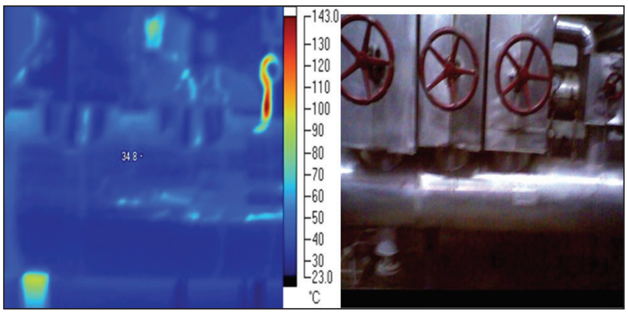

Figure 11. Insulation and measured temperature at the steam divider

3. Overview of parameters which are measured in facilities for industrial steam production in breweries 1, 2 and 3

Based on the previously described impact parameters, an analysis of the availability of measurements was performed on each of the three analyzed facilities, and it was found that there were differences in the availability of certain measurement data.

As boiler fuel in Brewery 1 and 3, oil is used, and in Brewery 2 gas is used. In all three breweries the total consumption of boiler fuel is measured. The total consumption of boiler fuel in Brewery 1 and 3 is measured by a metering lath, and in Brewery 2 a digital gauge is installed. For more accurate measurements of boiler fuel consumption, as well as easier determination of the optimal boiler load in Brewery 1 and 3, it is necessary to install separate digital boilers for boilers. In all three breweries, the composition and temperature of the combustion products at the exit from the boiler are measured. Only in the Brewery 2 is the automatic control of the content of oxygen, i.e. sensors for measuring the content of oxygen in flue gases and a system for combustion control are installed. In Brewery 1, the amount of steam produced is not measured, which creates problems in determining the optimum boiler load. In all three breweries, the temperature in the water supply tank for thermal preparation and the amount of chemically prepared water that passes through the water softener is measured. Also, in all three breweries, the allowed temperature of the cooled water is measured from the removal and discharge of the boilers that are discharged into the environment. Measurement is performed, i.e. laboratory control: hardness, alkalinity and pH values from: water softener, condensate reservoir, water tank and boilers.

The insulation and temperature of the pipes and other equipment are inspected.

Table 2 gives an overview of the measurements in industrial steam generators in Brewery 1, 2 and 3.

4. Conclusion

This paper presents the state of availability of measurement data for parameters that influence the

Table 2. Overview of measurements in industrial steam production plants for Breweries 1, 2 and 3

Reccomendations	Brewery 1	Brewery 2	Brewery 3
Measurement of total consumption of boiler fuel for all boilers (measuring lath)	YES	YES	YES
Measurement of boiler fuel consumption separately for boilers (digital meters)	NO	YES	NO
Measurement of boiler fuel temperature	YES	YES	YES
Checking the characteristics of boiler fuel	YES	YES	YES
Measurement of the combustion product composition at the boiler output	YES	YES	YES
Measurement of the temperature of the products of combustion at the exit from the boiler	YES	YES	YES
Built-in automatic control of oxygen content, i.e. built-in sensors for measuring the content of oxygen in flue gases and a system for combustion control	NO	YES	NO
The condensate is returned from the process to the condensate reservoir	YES	YES	YES
Is there a condensate leak?	NO	NO	NO
Measurement of water passing through a softener for chemical preparation	YES	YES	YES
Measurement of water temperature in the feed tank (thermal preparation at 105° C)	YES	YES	YES
Measurement of the water that flows from the tank to the boilers	NO	NO	NO
Measurement ie. laboratory control: hardness, alkalinity and pH values from: water softener, condensate reservoir, water tank and boilers	YES	YES	YES
Measurement of cooled water from decomposing and boiling off boilers	YES	YES	YES
Control of the boiler offset device ie. measuring the conductivity of boiler water	YES	YES	YES
Measuring the quantity of steam produced	NO	YES	YES
Measure the pressure of the steam in the boiler	YES	YES	YES
Monitoring of load and compliance of boiler operation	YES	YES	YES
Checking the insulation and temperature of the pipes and other equipment	YES	YES	YES

resource efficiency in the production of industrial steam in the brewing industry. By comparing data for all three breweries, it is evident that there is a difference in the quantity and type of available measurement data, which affects the accuracy of the assessment of the state of the resource efficiency in these plants. For a valid evaluation of resource efficiency it is necessary to have a sufficient number of measurement data that are often not available on such plants. Measurement of the influence parameters, their monitoring and maintenance of values within the recommended limits is necessary for efficient use of resources, which ultimately reduces the negative impacts on the environment as a consequence of the operation of these plants.

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Efficiency of cooling tower depending on operating parameters of the power plant cooling system

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Abstract

Analysis of thermal power plants from the aspect of energy efficiency and their environmental impact is the imperative of the present. Therefore, the operation of the cooling tower, which is a part of the cooling system for technological water in the thermal power plant, is analyzed. The simulation model is based on data from normative testing and project documentation. The aim is to determine the effect of selected inlet parameters on the efficiency of the cooling tower in the GE Gate Cycle software, via the "design" and "off design" simulation models. The conducted research showed that the analyzed parameters influence the efficiency of the cooling tower and technological water cooling system. Consequently, simulations and impact analysis were performed with the simultaneous change of more operating parameters. A clearer picture was obtained of the interaction between the observed inlet parameters, thus creating the possibility of increasing the efficiency of the cooling tower and the technological water cooling system as a whole.

Key words: Wet Cooling Tower, Power Plant, Cooling Tower Efficiency, Exergy efficiency, Modeling

1. Introduction

The hyperboloid cooling tower was patented by Dutch engineers Frederick van Iterson and Gerard Kuypers in 1918, while the first larger cooling tower was built in Great Britain in 1924 at the Lister Drive plant. Previous studies show that great importance was given to the study of the influence of the cooling system components to its energy efficiency.

Al-Nimr [1] studied a mathematical model describing the dynamic thermal behavior of counter flow cooling towers. Here, the closed-form solutions for the transient and steady temperature distributions within a cooling tower were obtained. The author derived a mathematical criterion under steady-state conditions to determine the proper length of the cooling tower which is sufficient to ensure complete cooling of the hot water stream.

Fisenko and Petruchik [2] presented a mathematical model of the performance of a cooling tower which consists of two interdependent boundary-value problems, a total of 9 ordinary differential equations, and the algorithm of self-consistent solution. The first boundary-value problem describes evaporative cooling of water drops in the spray zone of a CT, and the second one relates to film cooling in the packing. Simulation of the both problems was carried out. A comparison between experimental data and calculated results showed that the model correctly describes the basic regularities of the cooling tower performance. For reasons of large droplet sizes, the authors neglected the evaporative cooling of water in the rain zone.

Hawlader and Liu [3] investigated mathematical and physical models governing the flow, mass, and heat energy of moisture in an evaporative natural draft cooling tower. The models consider the effect of nonspherical shape of water drops on the flow and heat and mass transfer. The results obtained are confirmed by experimental data.

Kloppers and Kröger [4, 5] gave a detailed derivation of the heat and mass transfer equations of evaporative cooling in wet cooling towers. They described in detail the Poppe and Merkel methods, as well as the number of transfer units (NTU) method. The governing equations of the Poppe method are extended to give a more detailed representation of the Merkel one. The differences in solution techniques of those two methods are described with the aid of the enthalpy diagrams and psychrometric charts. In [6], Fisenko and Brin presented a new two-dimensional mathematical model of the performance of a crossflow cooling tower. This model includes a positive feedback between the aerodynamics of a cooling tower and the rate of evaporative cooling. The self-consistent iterative algorithm of solution was proposed and discussed. The simulation results, which include the profiles of air temperature in the rain zone, were displayed. It was shown that the main parameter affecting the thermal efficiency of the tower is the average droplet radius. The range of change of the final droplet temperatures was calculated. In addition, many researches dealt with the issues related to the cooling towers operation, general settings, and development of different models for analysis of the cooling tower operation. Gan et al. (2001) also carried out research and experimentally measured the performance of the closed wet cooling tower. It has been shown that the efficiency of the cooling tower increases with the air flow rate and decreases with the increasing water flow rate. The efficiency increases slightly with the increasing wet bulb temperature of the supply air. It also elaborated on the use of CFD for performance evaluation of cooling towers in terms of cooling capacity and pressure loss or for optimum design of cooling towers, according to tube pitches and flow rates of supply air and spray water (Riffat et al., 2000). Hasan (2005) and Hasan and Siren (2002) presented a theoretical analysis and computational modeling of Closed Wet Cooling Towers (CWCTs). It was shown in simplified analytical models with an assumption of a constant spray water temperature. The results of the simplified CWCT model are integrated with CFD to assess the effects of air flow distribution inside the tower on its performance. Facão and Oliveira (2004) presented the analogy between heat and mass transfer in an indirect contact cooling tower to estimate the mass transfer coefficient and the result reported a deviation in experimental results of 53 and 90% (in a Sherwood number coefficient), depending on the use of the heat transfer coefficient from the Zhukauskas correlation or from CFD simulations.

Sarker et al. (2008) has carried out experimental measurements using bare and fin tubes at the heat exchanger to enhance the cooling capacity of the hybrid closed circuit cooling tower. Their results for cooling capacity and pressure drop concerning the variable air inlet velocities, wet-bulb temperatures, cooling water inlet temperatures and the air to cooling water volume flow rate ratio (G/W ratio) were presented. Heyns and Kröger (2010) investigated the thermal-flow performance characteristics of an evaporative cooler from the experimental results. It established also correlations for the water film heat transfer coefficient, air–water mass transfer coefficient and air-side pressure drop. Papaefthimiou et al. (2012) has developed a new model to simulate the processes taking place inside a closed wet cooling tower and also to investigate the effect of ambient air conditions on its thermal behaviour. The review of indirect evaporative cooling technology concerning current status and research is reported by Duan et al. (2012). This study will portend to be of an enormous implication in promoting the application of the indirect evaporative cooling technology in buildings and to contribute to realization of low carbon air conditioning for buildings and associated energy saving and carbon emission measures. Jiang et al. (2013) studied about the effect of the process water temperature and flow rates of the air, spray water and process water on the cooling capacity, wet bulb efficiency, heat and mass transfer coefficients in a cross-flow CWCT based on the fin-tube arrangement. The flow arrangement of the air and the process water was counter flow, while that of the air and the spray water was cross flow. The results are empirical correlations between the heat and mass transfer coefficients based on the influencing factors [7-15].

The aim of this study is to analyze the influence of the selected parameters of the technological water cooling system on the performance of the cooling tower [16]. The research polygon is the cooling tower at thermal power unit of 230 [MW] [17].

2. Creating simulation models in the Gate Cycle™ software

Using normative and design values for the cooling system [17], a simulation “design model” was set, which with sufficient accuracy describes the cooling process of technological water in the cooling tower. The model is made in the commercial software package Gate Cycle™. The software is used for designing and evaluating the performance of thermal power systems in the project and exploitation phase. The model has a satisfactory accuracy, i.e. the structural characteristics within the model do not deviate more than 10 [%] from its design values. After the "design" simulation model, the "off design" model is set. The design characteristics of the cooling system are locked in it. This enables the analysis of the influence of the selected process parameters of the technological water cooling system on the characteristics of the cooling tower [18-22]. Figure 1 gives a graphical interface of the "design" model of the technological water cooling system. Cooling system devices and appliances are symbolically represented by graphical elements [16,18,19].

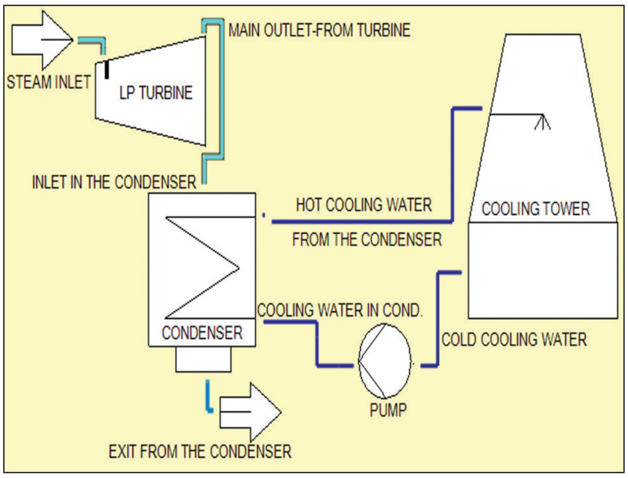

Figure 1. Display of the design model of the Cooling system

3. Selection of operating parameters of the technological water cooling system

For the analysis of the cooling system, a selection of process parameters was carried out, in the interval corresponding to the conditions during plant operation plant, in the spring period. Table 1 shows the selected parameters with the range of their change, as well as the defined step size.

Each of these parameters is analyzed separately. The simulation model varied the value of one of four parameters (e.g. ambient temperature (Ta) in the range of 12-22 [° C]) while the other parameters were unchanged. The same procedure was performed for all selected parameters.

4. Results of modeling

In the "off design" model, the influence of the operating parameters from Table 1 on the characteristics of the cooling tower was analyzed, such as exergy efficiency, Merkel number, air / water ratio, temperature range, temperature of approach and technological water losses. The simulation results as the value of a particular cooling tower feature in the function of the inlet parameters are summarized in one diagram for the entire change range. The diagram in Figure 2 shows the change in the exergy efficiency of the cooling tower in relation to the change in the value of the inlet parameters. The maximum value exergy efficiency of the cooling tower is at the lowest temperature of air entering the cooling tower (Ta). By increasing the temperature there is a significant drop in the exergy efficiency of the cooling tower. An identical situation occurs when the temperature of the hot water at the inlet of the cooling tower (Tcw) changes. By increasing the value of the cooling water temperature at the inlet of the cooling tower, the exergy efficiency of the cooling tower decreases. The opposite situation is when changing the relative humidity of the air entering the cooling tower (φa) as well as changing the hot water amount sent to the cooling tower (Qcw) for cooling .Increasing each of these parameters leads to a visible increase in the exergy efficiency of the cooling tower.

The diagram shown in Figure 3 attempts to present the influence of individual parameters on Merkel number. The diagram shows that the greatest impact on the value of Merkel number has the temperature of the hot water at the inlet of the cooling tower, with the increase of water temperature, Merkel number also increased to a value of 1.1. Analyzing other parameters and their impact on

Table 1. The range of the observed parameters

Parameter	Min.value	Max.value	Step
Ta	12	22	2[°C]
φa	30	55	5 [%]
Tcw	33	35,5	0,5 [°C]
Qcw	7250	8500	250[kg/s]

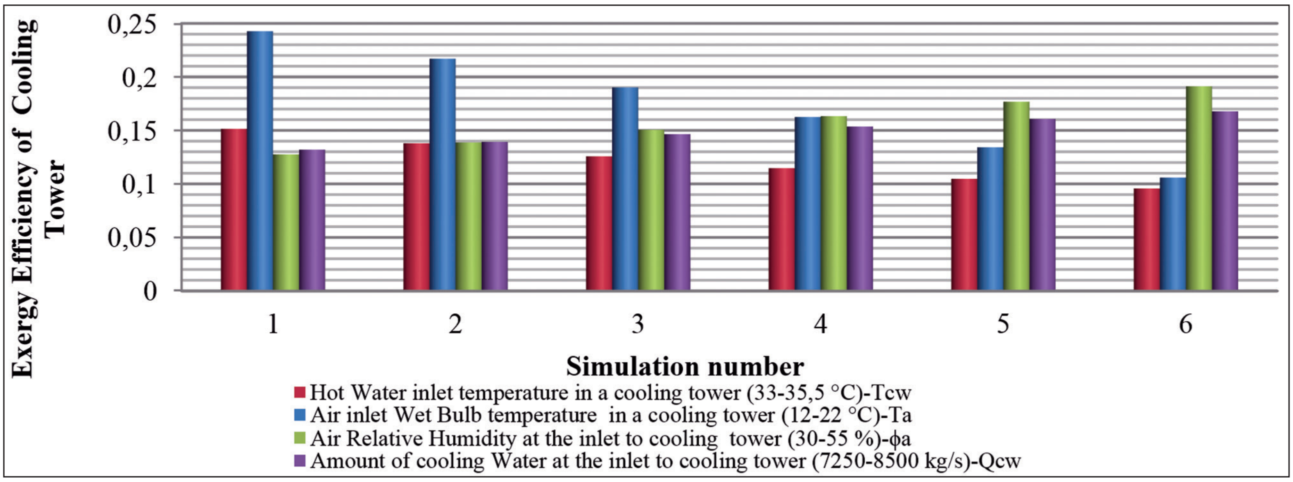

Figure 2. The exergetic efficiency of the cooling tower in function of inlet parameters

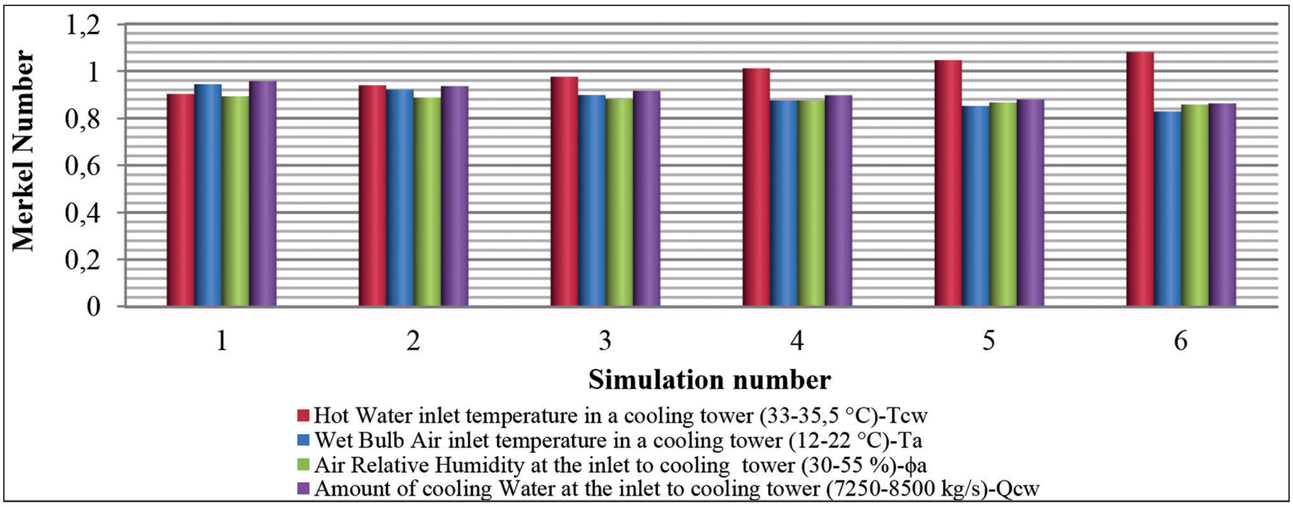

Figure 3. Merkel number in function of the inlet parameters

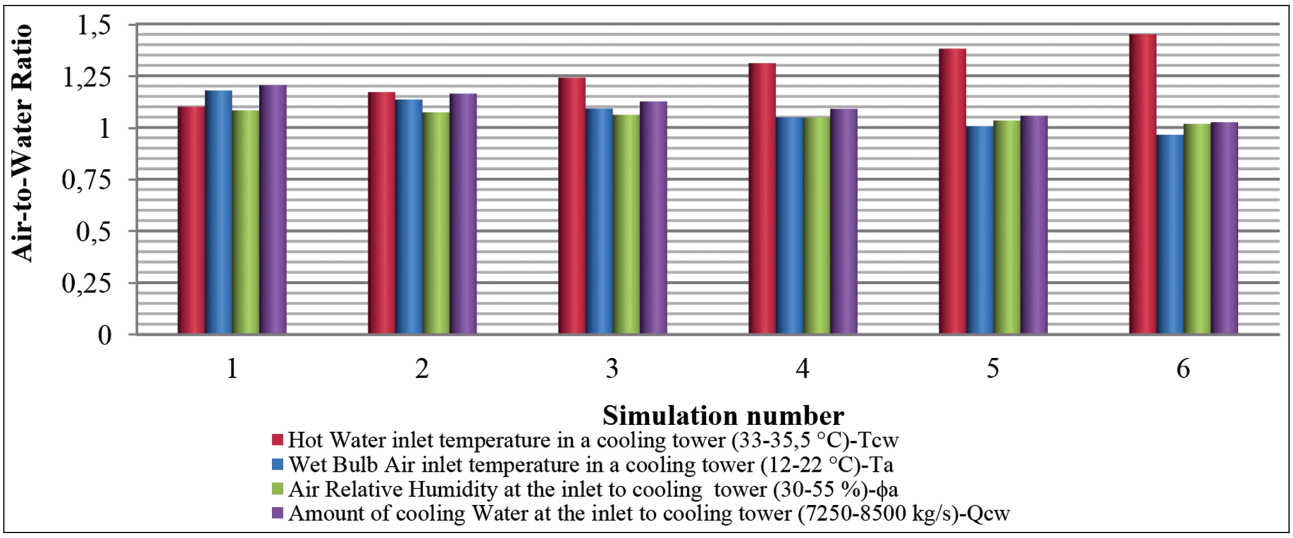

Figure 4. Air / water ratio in function of the input parameters

the Merkel number, it can be concluded that there are no significant changes. In general, the value of Merkel number decreased as the values of other parameters grew and ranged between 0.85-0.95. Merkel number for cooling towers most often has a value ranging from 1 to 5.

Another characteristic of the cooling tower which is considered, is the ratio of air/water. The diagram in Figure 4 gives the dependence of the air/water ratio on the value of the inlet parameters. This ratio is closely related to Merkel number. Accordingly, as in the previous case, the greatest influence on the increase of air/water ratio has the hot water temperature at the inlet of the cooling tower. The reason for this is the fact that the hot water temperature grows much faster than the cold water temperature. In order to keep the cooling tower characteristic the same, it is necessary to correct the air/water ratio. Other parameters analyzed in this paper, considerably less influence the change in the air/water ratio.

The diagram in Figure 5 shows the change in the temperature range of the cooling process, and for the different values of the inlet parameters. In these simulations, it has been shown that the greatest influence on the temperature range of the cooling tower has the change in the hot water temperature at the inlet of the tower, identical to the statement in the case of a change in the air / water ratio. Other parameters that have been analyzed have a partial effect on the temperature range of cooling. It is necessary to emphasize here that the temperature range of the cooling tower is defined according to the condenser needs and the cooling water flow velocity. The cooling tower does not have the ability to control either of the two parameters mentioned above.

The diagram in Figure 6 gives an approach temperature for different values of the analyzed operating parameters of the cooling system. The air tem-

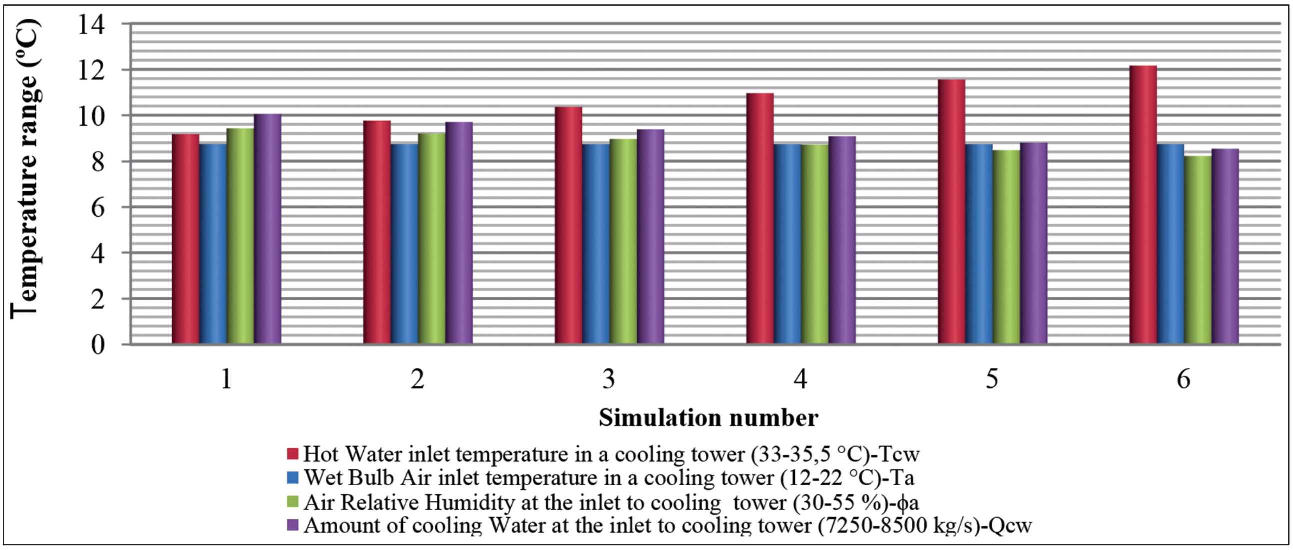

Figure 5. Temperature range in function of the inlet parameters

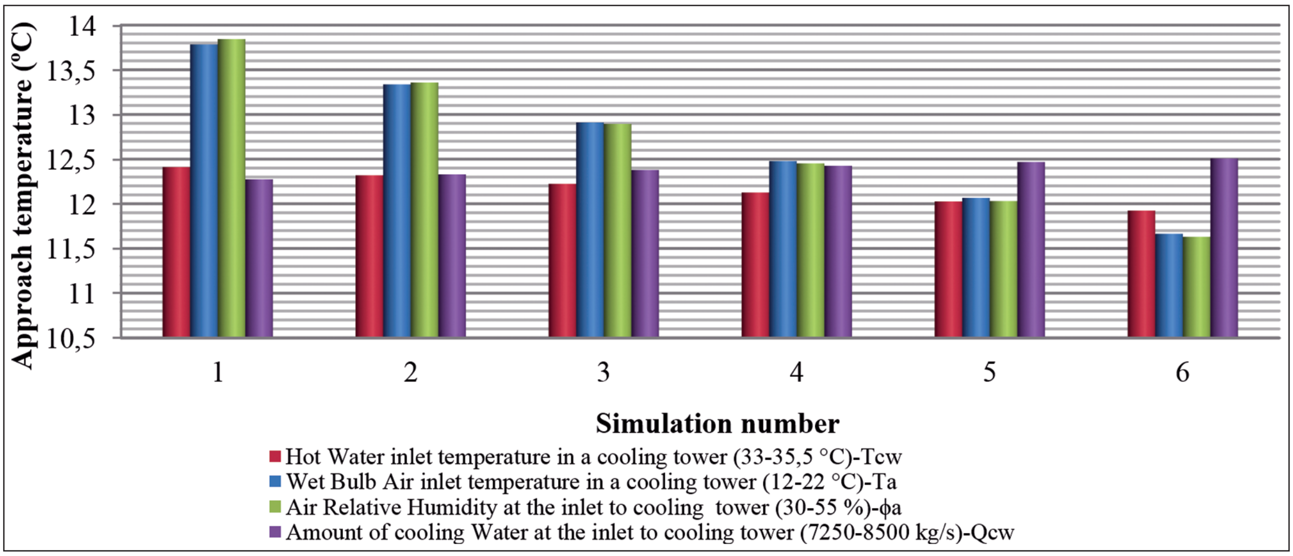

Figure 6. The approach temperature in function of the inlet parameters

perature entering the tower as well as the relative air humidity have an identical effect on the approach temperature. Increasing the value of these two parameters leads to a decrease in the approach temperature, which ultimately leads to higher efficiency of the cooling tower. Thus, by reducing the approach temperature, the cooling tower nears the temperature of the water at the exit to the ideal temperature of the outlet cooling water. On the other hand, the warm water temperature at the inlet of the tower has a slight influence on the approach temperature, while the amount of cooling water at the tower inlet has almost no effect on the approach temperature.

Proper and reliable operation of the cooling tower causes minimal losses of technological water. The diagram in Figure 7 shows the dependence of water losses on the value of the inlet parameters. The diagram shows that water losses oscillate when certain parameters change. The greatest water losses are in case the air temperature at the cooling tower inlet has the highest values, and the smallest is when the relative air humidity entering the cooling tower has the upper (highest) value of the analyzed change range. The hot water temperature and the cooling water amount at the tower inlet do not have significant effect on the increase or decrease in total water losses in the cooling tower.

Water losses during the operation of the technological water cooling system occur due to the evaporation of the cooling water, its blowdown and the drift of water droplets through the air flowing through the cooling tower. The value of water

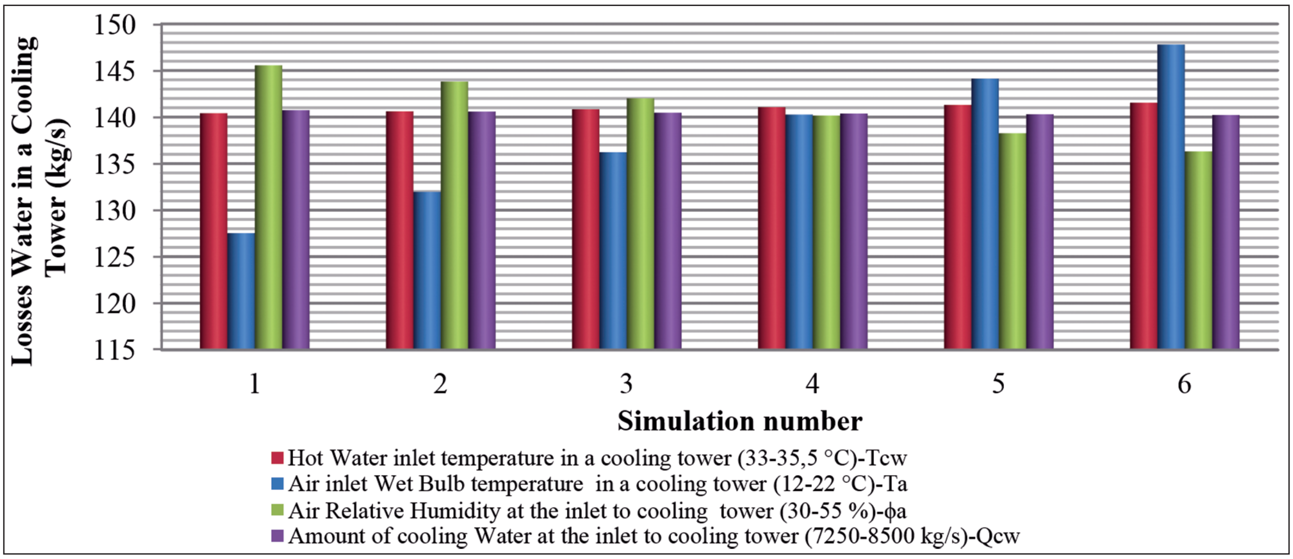

Figure 7. Water losses in the cooling tower in function of the inlet parameters

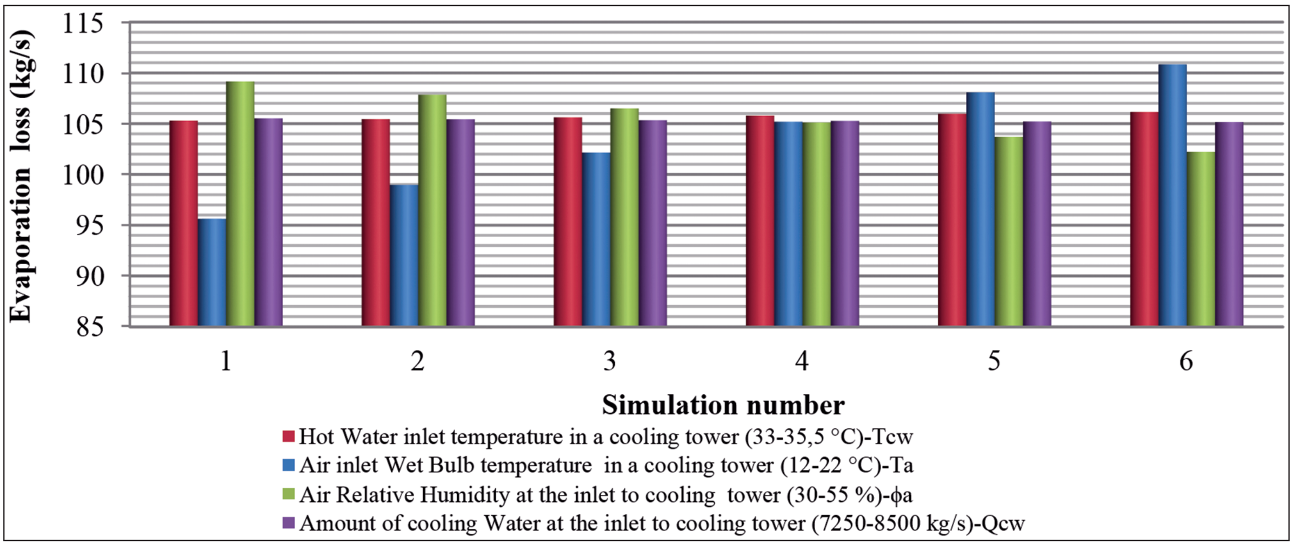

Figure 8. Water losses by evaporation in function of the inlet parameters

losses resulting from evaporation in the function of the analyzed parameters is given in the diagram in Figure 8. The largest water losses by evaporation are when the air temperature at the tower inlet has a maximum value, and the smallest losses are for the maximum value of the relative air humidity at the tower inlet. Higher air temperature prevents condensation of hot water, while higher relative humidity decreases the air power for additional moisture absorption. The other two parameters do not have a significant effect on water losses by evaporation. In percentage, this is the largest single water loss in the cooling tower.

The losses resulting from the cooling water blowdown process in the function of changing the values of the analyzed parameters are shown in the diagram in Figure 9. It should be emphasized that the losses due to the blowdown depend on the allowed concentration of salt in the cooling water, and that in this analysis they had different values depending on the parameters. The losses due to the blowdown increased as the values of the hot water and air at the cooling tower inlet were increased, and decreased by increasing the relative humidity of the ambient air and the amount of cooling water at the cooling tower inlet.

Cooling water losses resulting from the drift of water droplets by air flow, and for different values of inlet parameters, are shown in the diagram in Figure 10. The greatest influence on increasing this loss causes an increase in the relative air humidity at the cooling tower inlet. A smaller effect has the amount of cooling water at the tower inlet, while the increase in the value of the cooling water temperature at the tower inlet leads to a decrease in this type of technological water loss. The air temperature entering the cooling tower has no effect on this type of loss. Since the cooling tower is of natural

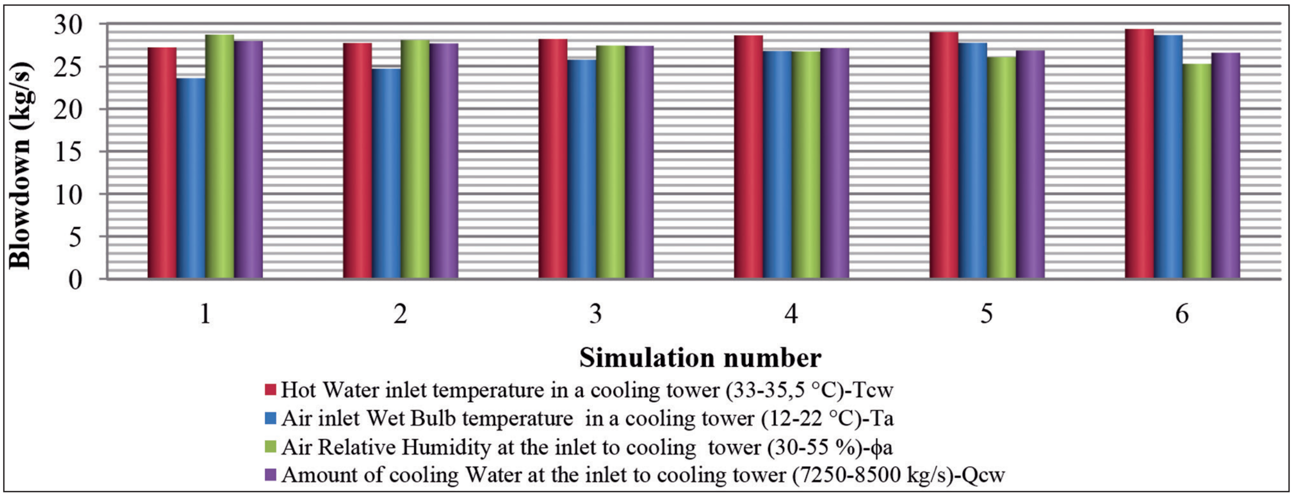

Figure 9. Water losses by blowdown in function of the inlet parameter

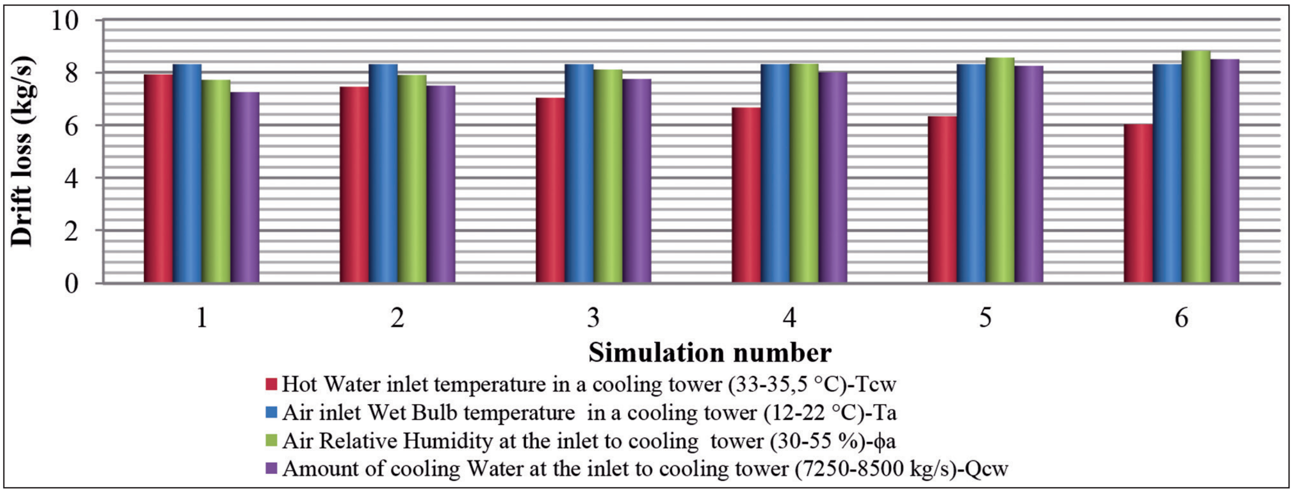

Figure 10. Water losses due to the drift in the function of inlet parameters

draft, there is no possibility of controlling the velocity of air flow as it is in a forced draft towers. Furthermore, this loss can only be corrected by regulating and managing the temperature of the inlet water and possibly the amount of cooling water.

5. Conclusion

In order to analyze the cooling process in the thermal power system which has a technological unit, a cooling tower with natural draft, a number of simulation models has been set up. Simulation models have given results for a certain range of inlet parameters values in the cooling tower. The aim of modeling and simulating different scenarios is to determine the influence of the analyzed parameters on the efficiency of the cooling tower, and hence the efficiency of the cooling system of the thermal power unit as a whole. For creating and validation of the simulation models, data from normative-project documentation were used. The basic characteristics of the technological water cooling system that are analyzed are: approach temperature, temperature range, exergy efficiency of the cooling tower, Merkel number, air / water ratio and water losses at the cooling tower. The conducted research clearly showed that the efficiency of the cooling tower and thus the efficiency of the technological water cooling system as a whole is influenced by all inlet parameters that are analyzed. Some parameters such as the cooling water temperature at the tower inlet and the relative air humidity had a significant effect on the efficiency of the cooling tower. On the other hand, parameters such as the amount of cooling water have less impact.

Accordingly, special attention should be given to the analysis of the influence parameters on the cooling tower performance. By applying this methodology to cooling towers of different geometric concepts, the obtained results can be used as a starting point when designing new or revitalizing existing cooling systems of a thermal power plant.

Bearing in mind the situation in the field of energy efficiency and environmental load, such an analysis of the cooling tower operation has a qualitative approach to the problem of increasing the resource and energy efficiency of the thermal power plant.

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Management of value-added wine waste: The principal component and agglomerative hierarchical clustering of bioactive polyphenols from wine waste

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Abstract

Performed principal component and agglomerative hierarchical clustering analyses were used for grouping bioactive polyphenols obtained from Merlot and Vranac wine waste. Polyphenols are obtained with ultrasonic extraction technique from investigated *Vitis vinifera* L. wine pomace, like grape seeds, skins and stems, which can find further use in food and pharmacology industries as preservatives against microbes. The extracts showed strong antioxidant activity (EC_{50} from 0.37 to 2.02 mg L^{-1}) and antimicrobial activity against six Gram-positive, five Gram-negative bacterial strains and yeast *Candida albicans*. The valorization of the value-added wine waste is consistent with the concept of the sustainable and environmentally oriented wine industry and has an important economic advantage.

Key words: Wine pomace, polyphenols, statistical analyses.

1. Introduction

Grape cultivation is one of the main extended agro-economic activities in the world. A world wine production in 2014 was 269 899 679 hL [1]. During wine production, significant quantities of grape residues: seed, skin, stem and residual pulp are generated [2-4]. The amounts of the grape pomace generated from winemaking are dependent on the grape cultivar, fermentation process and the pressing pro-cess and the pressing process [5-6]. Grape seeds represent 2-5% of grape weight and constitute approximately 38-52% of solid grape pomace [4]. In the last years, it is estimated that 3% of pomace produced is reused for animal feed, for the production of brandy and oil (obtained from seeds). Other applications are fertilizer (obtained from pomace) and a possibility to improve thermal insulation on building construction [7-8].

It is known that grapes are rich in polyphenols, very important compounds for human health because of their antioxidant, anti-cancer, anti-inflammatory, antimicrobial and other biological properties [9-14]. During the process of wine production from grapes, a significant amount of phenolic compounds (soluble in water) passes into wine, but also a certain level of these compounds remains in the pomace [15]. Phenolic composition of pomace [10], stalks [16,17], seeds [11,18] and skins [19,20] of different grape varieties have been well documented. The antimicrobial activity of their extracts is barely studied [9-11], although there are published reports on their antioxidant capacity [21-23]. Because of the increased interest in the use of natural over synthetic compounds in the food industry, the grape polyphenols can be used as a functional food (dietary fiber), food processing (biosurfactants) and supplement (grape pomace power) [24].

In this study, statistical principal component and agglomerative hierarchical clustering analyses of correlations among contents of various classes of polyphenolic compounds, antioxidant and antimicrobial activities of Merlot and Vranac wine residues: grape seeds, skins, stems were investigated.

2. Material and methods

2.1. Chemicals and samples

Solvents and chemicals were obtained from Merck (Darmstadt, Germany). Chloramphenicol, streptomycin, and tetracycline were acquired from a local pharmacy. Nutrient agar and nutrient broth were purchased from Merck.

The wine pomace and grape stems of Merlot and Vranac grape varieties were taken from local wineries. One part of the pomace was used for separating grape seeds and skins. Dried grape stems were mixed in a grinder for 2 min and afterward used for extractions.

2.2. Ultrasound-assisted extraction

An ultrasound instrument (EI, Serbia) with a volume of 3 L, frequency of 40 kHz and input power of 500 W was used in the experiments. The samples were ultrasonic extracted with solvent system consisting of methanol : acetone : water : acetic acid (30:42:27.5:0.5) for 15 min, and then centrifuged (2500 x g) for 10 min [2]. After treatment, extracts were centrifuged for 10 min at 2500 x g and evaporated to dryness under vacuum rotary evaporator and diluted in methanol to a concentration of 0.1 g mL^{-1}.

2.3. Spectroscopic analysis

Total polyphenol content in selected extract samples was determined according to the spectrophotometric method previously described [24]. Results were expressed as milligrams (mg) of gallic acid equivalents (GAE) per gram (g) of extract dry matter (DM).

2.4. HPLC analysis

Phenolic composition of the extracts was analyzed by high-performance liquid chromatography (HPLC), previously filtered through a 0.45 μm pore size membrane filter. Agilent Technologies 1200 chromatographic system equipped with an Agilent photodiode array detector (DAD) 1200 with RFID tracking technology for flow cells and UV lamp, an automatic injector, and ChemStation software was used for the determination of individual phenolic compounds. The phenolic compounds in selected extract samples were determined according to HPLC method previously described [14]. The wavelengths for the detection were 280, 320, 360 and 520 nm for UV and 275/322 nm ($\lambda_{Ex}/\lambda_{Em}$) for fluorescence-detection analysis. The identification of compounds was achieved by the comparison of their retention times and spectral characteristics to original reference standard compounds. Results were presented as mg g^{-1} DM.

2.5. Antioxidant activity

Antioxidant activity of all extracts was estimated by the determination of the free radical scavenging activity of extracts by DPPH free radical test previously described [14]. An Agilent 8553 UV/VIS spectrophotometer was used with the detection wavelength of 515 nm. The antioxidant activities of investigated extracts were expressed as median efficient concentrations ($EC_{50,}$ mg L^{-1}).

2.6. Antimicrobial activity

The antimicrobial activity was determined against Gram (+) bacteria*: Clostridium perfringens* ATCC 19404, *Bacillus cereus* ATCC 8739, *Listeria monocytogenes* ATCC 7644, *Staphylococcus aureus* ATCC 8538, *Sarcina lutea* ATCC 9341, and *Micrococcus flavus* ATCC 40240; Gram (-) bacteria: *Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 9027, *Salmonella enteritidis* ATCC 13076, *Shigella sonnei* ATCC 25931, *Klebsiella pneumoniae* ATCC 10031, and yeast *Candida albicans* ATCC 10231. All of them were obtained from the American Type Culture Collection. The bacterial strains inocula were prepared from overnight broth cultures, and suspensions were adjusted to 0.5 McFarland standard turbidity (corresponding to 10^7-10^8 CFU mL^{-1}).

Disc diffusion method was performed using 100 μL of bacterial suspension on Mueller-Hinton agar (MHA, Torlak) in Petri dishes (diameter 90 mm). The discs (HiMedia Laboratories Pvt. Limited) were covered with the test samples (50 μL) and placed into the inoculated agar (20 mL). The inoculated plates were kept for 24 h at 37 ^{0}C. As a positive control, chloram-phenicol (30 μg $disc^{-1}$), streptomycin (30 μg $disc^{-1}$) and tetracycline (30 μg $disc^{-1}$) were used, and the solvent (methanol - 50 μL $disc^{-1}$) was treated as a negative control. As expected, methanol showed no inhibitory activity [25]. All tests were performed in triplicates. Antibacterial activity was represented as the zone of inhibition (in mm) against bacterial strains.

2.7. Statistical analyses

All the experiments were performed in triplicates. Values are presented as means ± standard deviation. Significant differences were determined by analysis of variance (ANOVA) followed by Tukey test.

Principal Component Analysis (PCA) and Agglomerative Hierarchical Clustering (AHC) were performed using statistical applications available for Microsoft Excel® (XLSTAT 2018) (Addinsoft 2018). XLSTAT 2018 was also used to perform Pearson correlation analysis [26].

3. Results and discussion

Plants produce polyphenols as a response to the negative impacts from the environment (UV radiation, various pathogens, fungi, *etc.*). All plant parts contain phytochemicals such as phenols in different quantities depending on the stage of plant development and the environmental influence.

By using ultrasonic extraction technique [2] for a short extraction period (15 min) at room temperature and with a small concentration of solvent phenolic extracts were obtained from different parts of wine by-products.

The applied spectrophotometric analysis of obtained grape seed, skin, stem, and wine pomace extracts provides fast information of the total polyphenolic contents in the tested wine waste (Table 1).

The highest content of polyphenols was in the grape seed extracts obtained from Merlot and Vranac wine pomace (105.16 and 113.25 mg g^{-1}, respectively), followed by extracts of stems (78.34 and 73.99 mg g^{-1}, respectively), wine pomace (58.06 and 67.40 mg g^{-1}, respectively), and gape skins (50.36 and 51.73 mg g^{-1}, respectively).

Significantly higher polyphenol content was found in seed extracts in relation to the other extracts and agrees with the published data for other varieties [10,12,21,26-29].

To determine more precisely the polyphenolic content and composition of investigated by-products, HPLC method was used. Results (Table 2) agree well with those obtained by spectrophotometric determination of total polyphenol contents.

The highest concentration of total flavonoids, determined by HPLC was in the Merlot and Vranac seed extracts (44.53 and 43.29 mg g^{-1}, respectively), followed by stems and pomace (from 19.45 to 20.33 mg g^{-1}), and skins (18.06 and 18.61 mg g^{-1}, respectively).

The main compounds in the seeds were flavan-3-ols (41.32 and 40.16 mg g^{-1}, respectively) and gallic acid (3.21 and 3.13 mg g^{-1}, respectively).

The skin extracts were rich in anthocyanins (30.91 and 31.24 mg g^{-1}, respectively) and flavon-3-ols (15.48 and 15.81 mg g^{-1}, respectively. Malvidin-3-glucoside was the main anthocyanidin found in skins and grape pomace followed by peonidin-, delphinidin-, cyanidin- and petunidin-3-glucosides.

The grape pomace also showed the higher content of flavan-3-ols (15.41 and 15.64 mg g^{-1}, respectively) and significantly small contents of phenolic acids (4.07 and 4.24 mg g^{-1}, respectively) and anthocyanins (2.68 and 3.01 mg g^{-1}, respectively). A similar content of phenolic compounds in seeds and skins was found by other authors [13, 14, 28-30].

HPLC analysis of extracts of stems showed that they were also rich in flavan-3-ols (14.42 and 15.30 mg g^{-1}, respectively) and small amounts of flavonols (3.45 and 3.51 mg g^{-1}, respectively). Souquet et al. [16] reported a similar composition of an extract

Table 1. Total phenols (mg g^{-1}) and antioxidant activity, EC_{50} (mg L^{-1}) of Merlot and Vranac wine waste

Wine waste	Variety	Total phenols	EC_{50}
Seed	Merlot	105.16 ± 0.93	0.41 ± 0.02
	Vranac	113.25 ± 0.89	0.37 ± 0.01
Skin	Merlot	50.36 ± 0.20	2.01 ± 0.09
	Vranac	51.73 ± 0.19	2.02 ± 0.07
Stem	Merlot	78.34 ± 0.40	0.91 ± 0.08
	Vranac	73.99 ± 0.28	0.93 ± 0.06
Pom-ace	Merlot	58.06 ± 0.31	1.20 ± 0.02
	Vranac	67.40 ± 0.38	1.16 ± 0.03

Data are expressed as mean ± SD (n = 3); nd -Not detected.

Table 2. Polyphenols (mg g^{-1}) of Merlot (M) and Vranac (V) wine waste

		Seed	Skin	Stem	Pomace
1	M	3.21 ± 0.07	1.36 ± 0.03	1.58 ± 0.03	3.28 ± 0.08
	V	3.13 ± 0.03	1.40 ± 0.02	1.43 ± 0.04	3.33 ± 0.07
2	M	nd	0.31 ± 0.03	nd	0.37 ± 0.03
	V	nd	0.44 ± 0.10	nd	0.41 ± 0.02
3	M	nd	0.35 ± 0.03	nd	0.42 ± 0.04
	V	nd	0.38 ± 0.02	nd	0.50 ± 0.04
4	M	nd	0.11 ± 0.01	1.07 ± 0.03	0.09 ± 0.01
	V	nd	0.13 ± 0.01	1.1 ± 0.03	0.11 ± 0.01
5	M	nd	0.15 ± 0.02	1.33 ± 0.04	0.11 ± 0.02
	V	nd	0.14 ± 0.01	1.40 ± 0.07	0.15 ± 0.01
6	M	nd	0.09 ± 0.01	nd	0.04 ± 0.01
	V	nd	0.11 ± 0.02	nd	0.06 ± 0.02
7	M	nd	0.09 ± 0.01	nd	nd
	V	nd	0.08 ± 0.01	nd	nd
8	M	nd	0.08 ± 0.01	0.91 ± 0.03	0.06 ± 0.01
	V	nd	0.07 ± 0.01	0.88 ± 0.04	0.08 ± 0.01
9	M	nd	0.04 ± 0.01	0.14 ± 0.01	0.04 ± 0.01
	V	nd	0.05 ± 0.01	0.12 ± 0.01	0.05 ± 0.01
10	M	7.62 ± 0.09	1.89 ± 0.04	2.31 ± 0.06	3.64 ± 0.12
	V	8.08 ± 0.11	2.02 ± 0.07	2.55 ± 0.05	3.84 ± 0.12
11	M	15.50 ± 0.13	8.95 ± 0.09	7.27 ± 0.10	10.60 ± 0.13
	V	13.88 ± 0.14	9.08 ± 0.11	6.55 ± 0.11	10.58 ± 0.12
12	M	10.34 ± 0.12	nd	2.46 ± 0.03	1.17 ± 0.03
	V	10.60 ± 0.13	nd	2.60 ± 0.03	1.22 ± 0.05
13	M	7.86 ± 0.10	4.64 ±0.03	3.38 ± 0.03	nd
	V	7.60 ± 0.09	4.71 ± 0.05	3.60 ± 0.02	nd
14	M	nd	1.83 ± 0.03	nd	1.03 ± 0.03
	V	nd	1.60 ±0.01	nd	1.03 ± 0.02
15	M	nd	1.28 ± 0.03	nd	0.20 ± 0.01
	V	nd	1.44 ± 0.02	nd	0.27 ± 0.01
16	M	nd	0.60 ± 0.03	nd	0.28 ± 0.03
	V	nd	0.58 ± 0.01	nd	0.24 ± 0.02
17	M	nd	2.73 ± 0.03	nd	0.13 ± 0.03
	V	nd	2.60 ± 0.03	nd	0.11 ± 0.01
18	M	nd	24.47 ± 0.19	nd	1.12 ± 0.03
	V	nd	25.02 ± 0.17	nd	1.36 ± 0.02

1-Gallic acid, 2-t-coutaric acid, 3-Caffeic acid, 4-Quercetin glucoside, 5-Rutin, 6-Luteolin glucoside, 7-Myricetin glucoside, 8-Kaempferol glucoside, 9-Quercetin, 10-(+)-Catechin, 11- (-)-Epicatechin gallate, 12- (-)-Epicatechin, 13-Procyanidin B2, 14-Delphinidin glucoside, 15-Cyanidin glucoside, 16-Petunidin glucoside, 17- Peonidin glucoside, 18-Malvidin glucoside. Data are expressed as mean ± SD (n = 3); nd -Not detected

of stems in Merlot from France and Anastasiadi et al. in some Greek grape varieties [13].

All investigated extracts showed strong antioxidant activity (Table 1). Extracts of Vranac were slightly stronger antioxidants (EC_{50} from 0.37 to 2.02 mg L^{-1}) than extracts from Merlot (EC_{50} from 0.41 to 2.01 mg L^{-1}). The highest antioxidant activity was shown in seed extracts (0.37 and 0.41 mg L^{-1}, respectively), followed by extracts of stem (0.91 and 0.93 mg L^{-1}, respectively), pomace (1.16 and 1.20 mg L^{-1}, respectively) and skin (2.01 and 2.02 mg L^{-1}, respectively). The strong antioxidant activity of seed extracts corresponds to the highest polyphenol content and suggests partial responsibility of phenolic compounds for the strong antioxidant activity of these extracts. Pomace and skin extracts showed slightly weaker antioxidant activity compared to the rest of the extracts, which was also observed by others [12,21].

The investigated extracts showed scavenging free radical activity which was in very good correlation with the content of total polyphenols, determined by spectrophotometric analysis (0.9239 ± 0.2789 and 0.9258 ± 0.2657, respectively) and with the concentration of total flavonoids, determined by HPLC analysis (0.7795 ± 0.4402 and 0.7804 ± 0.4559, respectively). The literature data also confirm antioxidant activity of seed and stem extracts and correlation with polyphenols [10, 18, 20].

The antimicrobial activity data for all investigated extracts and 3 antibiotics (positive control) against *Clostridium perfringens*, *Bacillus cereus*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Sarcina lutea* and *Micrococcus flavus* (Gram-positive) and *Escherichia coli, Pseudomonas aeruginosa*, *Salmonella enteritidis*, *Shigella sonnei*, *Klebsiella pneumonia* and *Proteus vulgaris* (Gram-negative strains) and *Candida albicans* (yeast) are given in Tables 3 and 4 (inhibition zones).

It is found that investigated extracts were in average more sensitive to Gram-positive strains compared to Gram-negative strains and yeast which is in agreement with literature data [10,11,30]. We assume that the difference in activity is caused by the different structure of bacterial walls in Gram-positive and Gram-negative bacteria. The values of antimicrobial activity were in agreement with results of HPLC analysis (Table 3).

The analysis of the Merlot and Vranac by-products shows that seeds have the highest antimicrobial activity in the range of 16.7 to 19.6 mm against Gram-positive and 14.8 to 17.5 mm against Gram-negative strains. The extracts of the stems (16.2 to 19.3 mm against Gram-positive and 14.0 to 17.7 mm against Gram-negative strains), the extracts of skins (15.6 to 18.5 mm against Gram-positive and 13.0 to 16.6 mm against Gram-negative strains), and the extracts of pomace (14.8 to 17.3 mm against Gram-positive and 12.1 to 15.8 mm against Gram-negative strains). All of the tested extracts exhibited satisfactory antimicrobial activity against *Candida albicans* (yeast) in the range of 13.1 to 15.5 mm.

The highest antimicrobial activity of the investigated extracts was shown against Gram-positive strains: *Sarcina lutea, Listeria monocytogenes* and *Staphylococcus aureus* (inhibition zones in the range from 18.1 to 19.7 mm) and against Gram-negative strains *Shigella sonnei* and *Pseudomonas aeruginosa* (inhibition zones in the range from 15.0 to 17.7 mm). The obtained results are similar to the results of other authors, who perform investigations on different grape varieties against some bacterial strains [11-14,30]. Statistical analyses of correla-

Table 3. Antimicrobial activities (inhibition zone diameters, mm) Merlot (M) and Vranac (V) wine waste (50 µL disc^{-1}) and reference antibiotics: Streptomycin (Str), Chloramphenicol (Chl) and Tetracycline (Tet) (30 µg disc^{-1}) against Gram-positive strains

		I	II	III	IV	V	VI
Seed	M	17.7 ±*1.3*	17.1 ±*1.0*	18.3 ±*1.2*	18.5 ±*0.9*	19.4 ±*1.3*	16.7 ±*1.2*
	V	17.5 ±*1.2*	17.1 ±*1.2*	18.4 ±*1.3*	18.5 ±*1.3*	19.6 ±*1.0*	16.9 ±*1.1*
Skin	M	16.7 ±*1.3*	16.2 ±*1.0*	17.2 ±*1.0*	17.3 ±*1.0*	18.1 ±*1.2*	15.7 ±*1.1*
	V	16.9 ±*1.0*	16.3 ±*1.2*	17.4 ±*1.0*	17.2 ±*1.0*	18.5 ±*1.2*	15.6 ±*1.3*
Stem	M	17.2 ±*1.3*	16.8 ±*1.3*	18.2 ±*1.2*	18.1 ±*1.3*	19.0 ±*1.4*	16.2 ±*1.1*
	V	17.4 ±*1.3*	16.9 ±*1.3*	18.5 ±*1.2*	18.2 ±*1.2*	19.3 ±*1.1*	16.4 ±*1.1*
Pom-ace	M	15.9 ±*1.2*	15.2 ±*1.2*	16.3 ±*1.3*	16.4 ±*1.3*	17.3 ±*1.3*	14.8 ±*1.0*
	V	15.9 ±*1.1*	15.3 ±*1.0*	16.5 ±*1.1*	16.4 ±*1.2*	17.3 ±*1.3*	15.1 ±*1.3*
Str		nt	nt	nt	nt	nt	nt
Chl		nt	26.0 ±1.1	25.0 ±1.2	18.0 ±2.0	38.0 ±2.0	35.0 ±2.1
Tet		29.0 ±*2.0*	23.9 ±1.0	18.5 ±1.3	18.7 ±1.2	20.0 ±1.2	23.6 ±0.7

I - Clostridium perfringens, II - Bacillus cereus, III- Staphylococcus aureus, IV- Listeria monocytogenes, V- Sarcina lutea, VI - Micrococcus flavus

Table 4. Antimicrobial activities (inhibition zone diameters, mm) of Merlot (M) and Vranac (V) wastes (50 µL disc^{-1}) and reference antibiotic (30 µg disc^{-1}) against Gram-negative strains and yeast

		VII	VIII	IX	X	XI	XII
Seed	M	14.8 ±0.7	15.6 ±0.9	15.1 ±1.0	17.4 ±1.2	16.1 ±1.0	15.2 ±1.1
	V	15.7 ±1.2	15.9 ±1.2	15.4 ±1.1	17.5 ±1.2	16.1 ±1.3	15.5 ±0.9
Skin	M	13.0 ±1.1	14.4 ±1.0	14.0 ±1.2	16.3 ±1.3	15.7 ±1.2	14.3 ±1.0
	V	13.3 ±0.7	14.3 ±0.9	14.0 ±0.8	16.6 ±0.8	15.2 ±1.4	14.3 ±0.9
Stem	M	14.1 ±1.2	15.6 ±1.3	15.2 ±1.1	17.6 ±1.3	16.6 ±1.1	15.1 ±1.0
	V	14.0 ±1.0	15.4 ±1.0	15.1 ±1.2	17.7 ±1.0	16.5 ±1.1	15.2 ±1.0
Pomace	M	12.1 ±0.8	13.5 ±1.1	13.0 ±0.9	15.8 ±1.3	15.0 ±1.2	13.1 ±0.7
	V	12.7 ±1.2	13.7 ±1.2	13.3 ±1.0	15.6 ±1.3	15.1 ±1.3	13.3 ±1.3
Str		16.0 ±1.2	23.0 ±1.0	18.0 ±1.0	19.0 ±2.0	nt	nt

VII- Escherichia coli, VIII- Pseudomonas aeruginosa, IX- Salmonella enteritidis, X- Shigella sonnei, XI- Klebsiella pneumoniae, XII- Candida albicans

tions among contents of various classes of polyphenolic compounds in extracts of both Merlot and Vranac wine residues, determined by HPLC analysis, antioxidant (AA) and antimicrobial activities against Gram-positive and Gram-negative bacteria and *Candida albicans* yeast were performed.

Phenolic acid (PA) and flavonols (FOS) are in a strong positive correlation (0.909). On the other hand, antioxidant activity (AA) is in the medium negative correlations with the antimicrobial activities of Gram-positive bacteria-*L. monocytogenes* (LM) (-0.646), *M. flavus* (MF) (-0.655), and Gram negative bacteria-*E. coli* (EC) (-0.709), *P. aeruginosa* (PA) (-0.689), *S. enteritidis* (SE) (-0.650), *S. sonnei* (SS) (-0.632). Antimicrobial activity of *C. perfringens* (CP) is in a strong positive correlation with antimicrobial activities of all investigated bacteria (*B. cereus* (BC) (0.982), *S. aureus* (SA) (0.972), LM (0.974), SL (0.983), MF (0.962), EC (0.901), PA (0.954), SE (0.956), SS (0.951) and *K. pneumoniae* (KP) (0.902). The similar strong positive correlations were observed among other Gram positive and Gram negative bacteria.

In the first step of statistical evaluation, the Kolmogorov-Smirnov test (the significance level α was 0.05) was used to test the normality of data. Data included obtained total phenolic acids, total flavonols, total flavan-3-ols, antioxidant and antimicrobial activities (expressed as inhibition zones) of all investigated Gram-positive and Gram-negative bacteria.

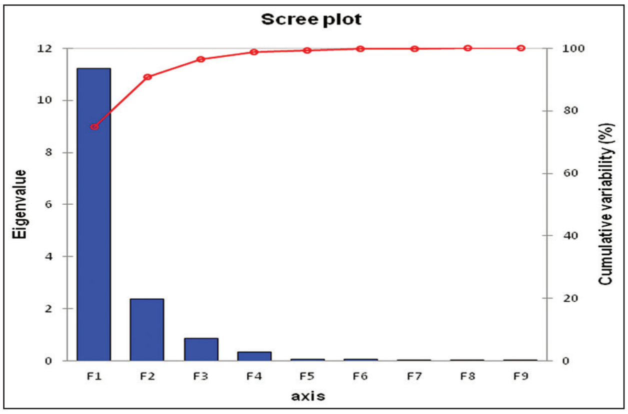
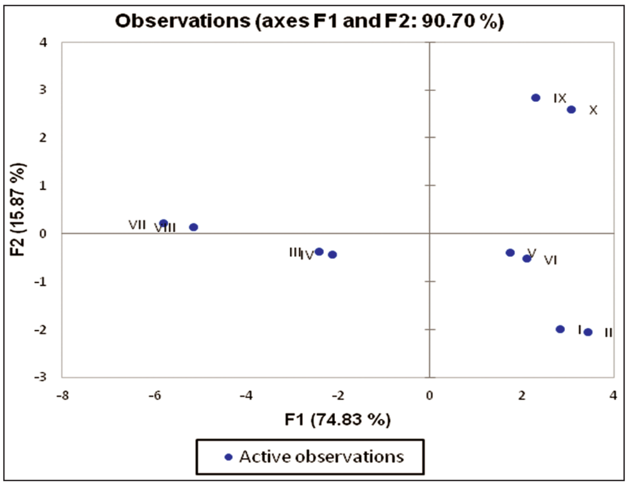


Figure 1. Scree plot. In this plot, the eigenvalues are sorted from the largest to the smallest

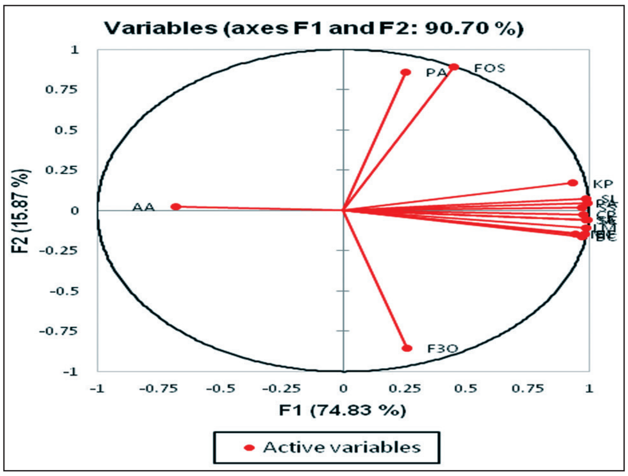
Before PCA analysis, the data matrix was tested to detect outliers. Grubb's test was used with experimental data, and no outliers were found. From the shape of the scree plot, shown in Figure 1, the number of important components that were used in further calculations can be seen.

The PCA of the dataset revealed the presence of two components with characteristic (Eigen) values (11.224 and 2.381) exceeding 1. This two-component solution explained a total of 90.697% of the variance, with 74.826% contributed by the first component, and 15.871% by the second component. PCA scree plot shows that samples I, II, V, VI, IX, and X (the extracts of seeds and stems) contain higher contents of phenolic acids (positive values in PC1), and samples III, IV, VII, and VIII (the extracts of skins and pomace) lower concentrations of total phenolic acids (negative values in PC1).

On the other side, VII-X (pomace extracts) contain higher concentrations of flavonols, and samples I-VI (seed, skin, and stem extracts) lower concentrations of flavonols (negative values in PC2) (Figure 2a).



a)



b)

Figure 2. Principal Component Analysis (PCA). a) PCA scree plot of the first major component 1 (PCA1) versus the second component (PC2); b) Loading plot of the first main component (PC1) versus the second component (PC2).

Loading plot shows very similar values for both Gram-positive and Gram-negative bacteria, with AA as the only parameter with the negative value in F1 (Figure 2b).

Agglomerative hierarchical clustering (AHC) of the standardized variables using the Ward method as an amalgamation rule was performed with a squared Euclidean distance as a measure of the proximity between the samples. The obtained dendrogram presenting the clustering of the analyzed samples is presented:

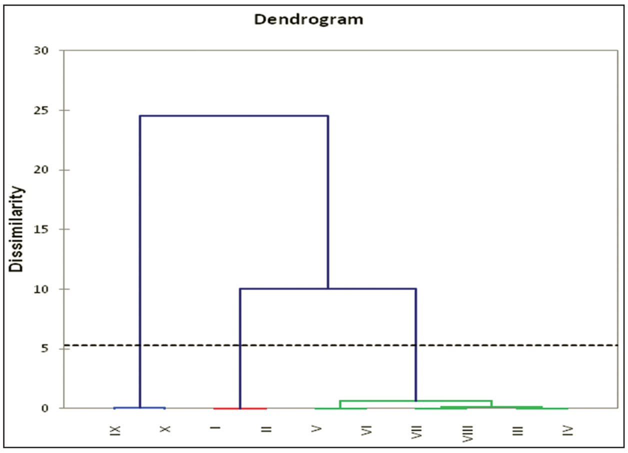


Figure 3. Dendrogram derived from the obtained results on the basis of the extracts of Merlot and Vranac wine waste

The dendrogram in Figure 3 shows that all monitored samples could be grouped into three main clusters presented using different colors. Cluster I includes samples with the concentrations of phenolic acids of more than 10 mg g^{-1} and cluster II includes samples with no detected flavonols: I and II (the extracts of seeds from Merlot and Vranac wine waste), and cluster III includes samples III-VIII (the extracts of skins, stems and pomace from both Merlot and Vranac wine waste). Thus, this cluster analysis was not able to distinguish samples based on the grape variety, but it was successful to make a difference among parts of the grape; seeds show different properties compared to skins and stems, which apparently were the major ingredients in the pomace.

4. Conclusions

Vine is a powerful plant which is rich in polyphenol compounds even in by-products after vinification process. Those compounds are responsible for strong antioxidant and antimicrobial activities of grape, wine, and its by-products.

Performed principal component and agglomerative hierarchical clustering analyses were shown as good tool for grouping and distinguishing results from wine by-products from both investigated grape varieties based on the content of various polyphenolic classes, antioxidant and antimicrobial activities. The seeds showed the strongest antioxidant and antimicrobial activities followed by extracts of grape stem and skin from wine pomace.

The valorization of the value-added wine waste is consistent with the concept of the sustainable and environmentally oriented wine industry and has an important economic advantage.

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Computer management, regulation and control of mechatronic systems

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Abstract

Mechatronics is a new interdisciplinary field, which is based on a synergetic combination of high precision mechanical engineering, electronic control and information systems in design of products and processes. Modern machines are sets of mechanical, electronic and information technology, closely coupled and linked to the most effective way to performed and executed the given action. Such systems require a high level of automation with software for monitoring, control and management processes (SCADA Systems) using specially customized programmable logic controllers (PLC). Application of these systems is particularly pronounced in the highly productive machines which require the use of synergies and functional control subsystems, information subsystems with subsystems interrelationships, sensor subsystems with ability of separation of useful signals, actuator subsystems for transformation of the original energy into useful work, and mechanisms to carry out the desired movement in the function process.

Key words: mechatronics, control, regulation, SCADA system, PLC controller.

1. Introduction

The term mechatronics was developed in Japan in the late sixties [1]. Although there are many definitions of mechatronics, the most common is that mechatronics is interdisciplinary field, which is based on the synergetic combination of high precision mechanical engineering, electronic control and information systems for design products and processes [2]. The system represents the totality of physical and chemical processes and resources for their achievement with specific purpose to operate independently in given environment [3]. Today, most machines are mechatronic systems, which are implemented using the functional subsystems such as control and information subsystems, interconnected subsystems, sensor subsystems with ability of separation of useful signals, actuator subsystem for transforming of original energy into useful work, and mechanisms to carry out the desired motion as a function of the process. A typical mechatronic system is reading the signs, processes them, and as a result produces force and motion. Mechanical systems have been expanded and connected with sensors, microprocessors and controllers (controllers). Integration of functional subsystems engineering, electronics and information technology is a basic structure of mechatronic systems [4]. Mechatronic system must be understood as a whole of partial systems: basic system (mostly mechanical), actuators, sensors and a processor and data processing processes [5].

2. Computerized management of mechatronic systems

Unlike the recent past when it was thought that the world we live in consists of energy and matter, today we are witnessing that in the 21 century prevailing opinion that the world consists of energy, matter and information. In technical and technological terms, the information is carrying signal, whose creation, transmission, processing and use is determined by a new postindustrial era, called information and telecommunication technologies era. Postindustrial era is based on information technologies to manage information as a basis for defining development strategies of each production system. Today, the automation tasks are solved with especially efficient, universal and standard, basic functions: *supervision, control* (series of decisions taken by the operator for their achievement), control (instead of the operator's role of control over production processes regulator perform simple operations without direct control or presence of a man) with computer processing in real time [3,6]. Unlike conventional, programmable measurement system has an electronic circuit for processing the measuring signals, the logic of control and eventually a permanent record of the signal on the device for registration and multi-channel writing. To make this all possible physical values first must be converted into corresponding electr ical signals by transducers that transform the w ay - move, pressure, temperature, liquid level, velocity and flow into an electrical signal that can be defined with the following levels: a volta ge signal high level (0-24) V DC voltage, low vol tage signal level (0 to several tens of mV), a standardized current signal (0-20) mA or (4-20) mA. SCADA (Supervisory Control and Data A cquisition) systems (or SCADA network) are softwares for monitoring, control and management of industrial processes. SCADA stands for "pure" software package resting on the hardware that works, generally through the processing electronic devices (IED - Intelligent Electronic Devices), or through other commercial hardware modules in order to monitor a process with the ability to control the same. Flow control process, quality control, production, management and the desire d direction is unthinkable without the use of measurement techniques [4]. The task of realiz ation of such objectives in the management of th e production process and sets the following questions: what is the purpose of measurement, method and manner with which the measurement was made, what is the effect and accuracy of measurement, what is the response rate measuring device? Measuring member which consists of a measuring transducer (sensor) and a measurement converter has the task to measure - felt regulated size and transfer it for further processing.

Programmable logic controllers (PLC) as components of SCADA systems are industrial PCs whose hardware and software is specifically adapted to work in industrial conditions which can be easily programmed and installed into existing industrial systems. Basic form of PLC is mainly used to implement certain logic functions that are mapped from the sensor signals to signals that are transmitted to the actuators. PLC is expected to periodically read (inserts) signals from the sensors, performs a number of arithmetic-logic operations (in accordance with a given function) whose results are transferred to the executive parts, or some other indicator devices.

PLC controller is different from general-purpose computer system because it has no external memory (disks), and a number of standard input / output equipment. In addition, its operating system is simpler and gives comparatively less able than general purpose computers. In fact, PLC was conceived and designed for a relatively narrow and clearly defined scope of work related to supervision and management of individual devices, as a result of his outstanding efficiency and simplicity. Scope of the PLC controller is the same as for specialized microcomputer controllers or signal processors.

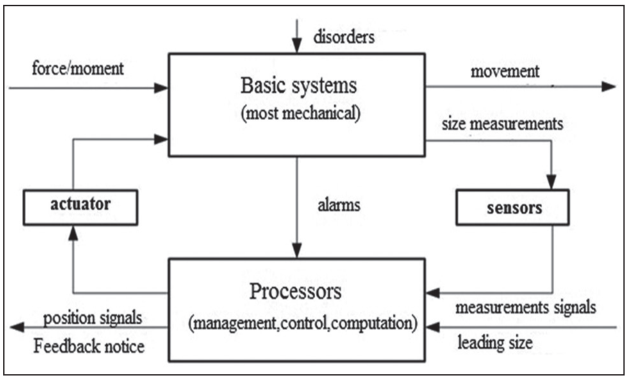

Figure 1. General structure of mechatronic systems

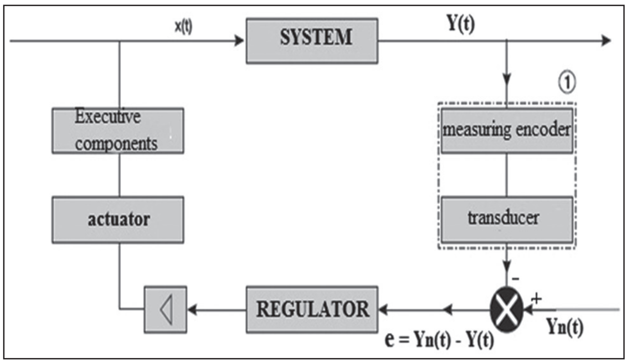

Figure 2. The basic logic block diagram of control with measuring devices

3. Example of possible performance of mechatronic control, regulation and control of pumps on hydraulic excavator

Hydraulic excavators as mechatronic systems are composed of several basic subsystems. The main subsystems of excavators are the subsystem of mechanism of transport, the subsystem of the mechanism of circular motion, propulsion subsystem, hydraulic subsystem, the subsystem of the mechanism of digging, electrical subsystem. System management, regulation and control in these types of machines should consist: control parts, the central control system, pump control system, integrated system for control and monitoring, data acquisition cards, proglamabilnog logic controllers, sensors and switches.

The role of the *pump control system* (PMS) is that with excessive regulation ensures optimum utilization of installed engine power or current engine power. Electronic control pumps preventing the machine that requires more hydraulic power than installed engine can provide. PMS (pump control system), together with the electro - hydraulic servo control should enable optimal interaction between the hydraulic drive and work movement. Movements that would be required would be recognized by microcontroller which should scan the operational elements (the control handles, pedals), and transfer them to the electro-hydraulic valve.

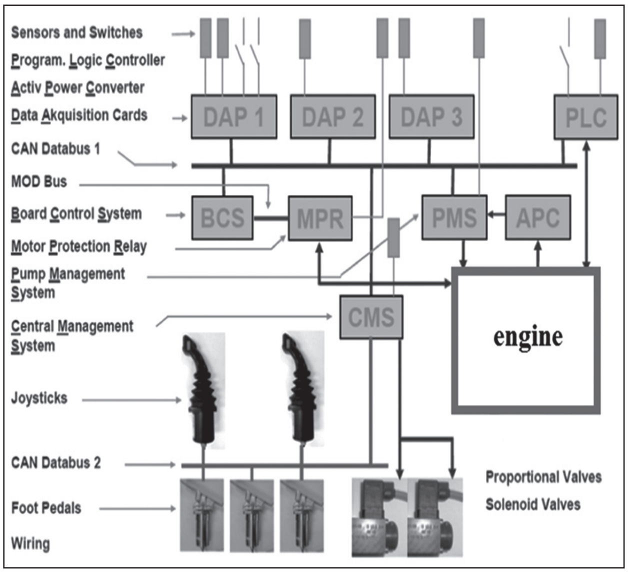

Figure 3. Mechatronic system of hydraulic excavator

Installed microprocessor role will be to ensure that the output of hydraulic pump power corresponds to the actual optimal conditions for handling the control and reversal of hydraulic pump dependent of changes in the flow of oil, whose volumetric flow rate and direction proportional to the movement of control joystick and pedal. The working principle of oil-hydraulic pump drive system should be implemented as follows: The value of control signal (pressure) gives a pressure regulating valve, so that the control signal from the operator (wheel excavator) leads in the form of electrical signal size of 225 - 850 mA to actuator control valve for pressure regulation, and relatively the same intensity of electrical signal is transformed into hydraulic control signal with intensity proportional to the size of the control signals in the form of pressure in the range of 4-72 bar. Servo hydraulic splitter 3 / 3 receives the control signal from the valve for pressure regulation and affects the position of the hydro-cylinder two-way action with a rod to regulate the bevel-plate axial piston pumps. This means that during work delivers just as much hydraulic oil as needed to run the relevant work movement. In the neutral position the control handle, the pump would automatically reverse the flow to zero. Such performance hydraulic system would offer the following advantages: minimal power losses, reduced the temperature of hydraulic oil, the higher life of hydraulic pumps and engines. Regulation of the pump on excavator would be performed through the proportional valve, which would set the controls of the pumps. The entrance to the proportional valve was associated with 70 bar system pressure. Each of the pumps should be equipped with a pressure regulator control, and the effect of the regulator would regulate pump management system (PMS). Depending on engine load situations, the effect would be regulated by pressure in the range from 7.5 bar to 42.5 bar. When the control pressure is 42.5 bar pump would be rotated to the maximum flow rate.

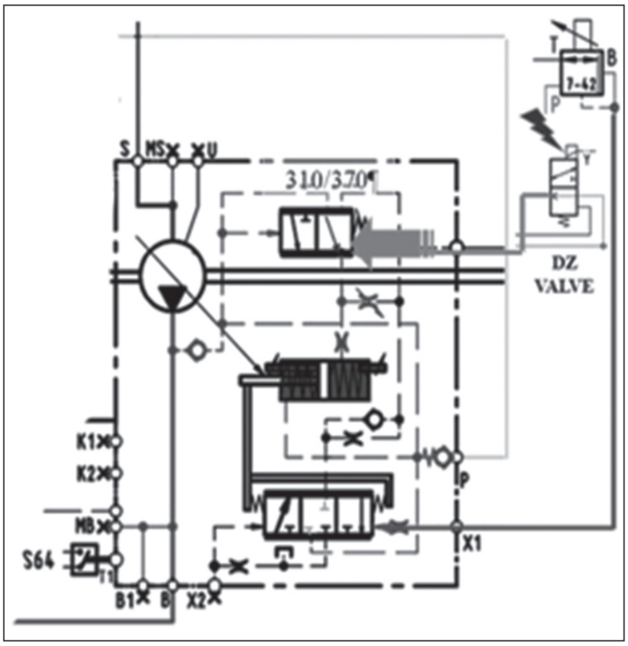

Figure 4. Regulation of hydraulic system

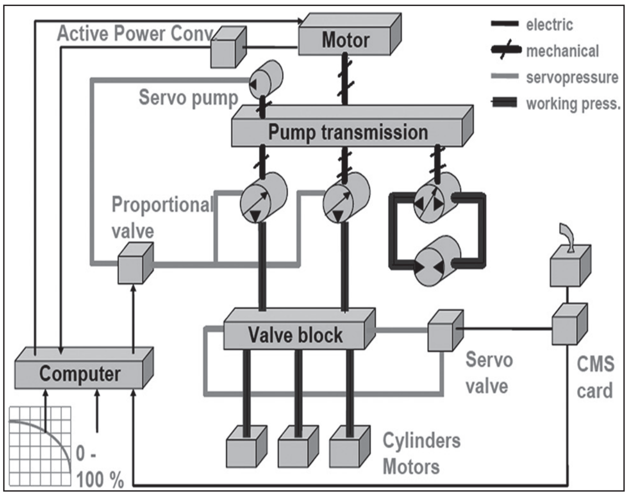

Figure 5. PMS system and PMS regulation

When the control pressure is 7.5 bar pump would be rotated back to "zero" flow velocity. The regulator would be controlled by electromagnetic proportional valve connected to the electrical load limit controller (PMS). The regulator of limits the load (PMS) would enable full use of available engine performance. So any number of shuttles hydraulic pumps and uncontrolled consumer would be able to get the power from one engine. Provided the suction power of consumers would be less than the effect of the engine, but the regulator could have an impact only on alternating pumps. The regulator would use the actual power consumption of the engine as a signal for starting the variability as soon as consumers begin to demand more power than is available to engine efficiency. PLC controller of such system would carry out the function of switching on and off the motor, control system, central lubrication, controls, sensors, voltage control, switching on and off the control panel for a visual overview of the system.

4. Conclusion

Application of mechatronics in the highly productive hydraulic machines is represented more than ever before. The hydraulic system is the one on the most important parts of most of these machines, and even up to 50% of machinery failures and delays with the hydraulic system are caused by the failure of precisely the same system because the hydraulic system of construction and mining machinery is complex nonlinear dynamic system. Apart from the classical mechanical parts most subsystems on these machines for its configuration is electromechanical- mechatronics because it combines mechanical parts, hydraulic components and electrical systems. Hydraulic subsystem is also multifaceted, because he has mechanical, hydraulic and electrical components. Traditional methods for monitoring and diagnosis of failure in these systems are inefficient, often unreliable, and most importantly, finding and repairing faults of such methods take a very long time. By contrast the introduction of the distributed monitoring system is closely associated with the installation of mechatronic components for hydraulic machinery would enable better data acquisition, control, regulation and management of these systems. The application of mechatronic approach in designing, constructing new and reconstructing existing highly productive machines such as hydraulic excavators is the only way to increase reliability, safer and more precise control, management and regulation of the entire system. In addition to getting a higher level of control, management and regulation, economic viability is still one of the main reasons for the application of mechatronics on hydraulic machines.

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