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THEORETICAL ANALYSES OF FEED- AND ENERGY-PURPOSE BIOMASS PARAMETERS

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Abstract

In Hungary utilization of biomass for energy production is of great importance. A research project supported by the Hungarian Scientific Research Fund (OTKA-K-68103) has been initiated to identify parameters determining energy yield and efficiency of using different chopped raw materials. According to the Hungarian circumstances maize produced for biogas generation has been selected for further investigation aiming at identifying optimal chopped-bulk structure. Parametric description of chopped material structure has been developed and its effect on quality and quantity of biogas is being evaluated. Other area of the research is dedicated to theoretical questions of burning chopped biomass. For preliminary investigation arboreal plants (firewood) has been selected which – with the purpose of substituting it as biomass for a part of fossil fuels – has been used on an industrial scale. Its structure is mainly congeries of cuttings, chips or similar substance of eclectic size distribution.

1. Analysis and geometric description of chopped maize structures

For describing physical form and geometry of chopped materials (as an important influencing factor for energy transformation), its structure needs to be analyzed. Such methods are mentioned in literature each assuming that chaff bulk is homogenous. This approach is highly inadequate and causes 60% difference in the projected surface area of chaff bulks [1].

Inhomogeneous feature of chaff bulks can be originated in the plant-biological reasons. Plants namely consist of more parts (stalk, leaf, crop) differing definitely from each other not only in shape but also in density and - what is really important from the point of energy purpose utilization - in heating value. The chopping harvest technology has been developed to fine bulks consisting mainly of stalk and leaves fractions, and for this reason chop-length-homogeneity can only be assured for these fractions. Oscillations in chopping construction, slip in compressing set, oblique feed of stems and their limited length contribute in every case to scatter of chop length. For this reason, the most adequate chop-length distribution model [2] if maize kernels are in milk-ripe stage interprets chopped-bulk by means of a 6 parameter blend distribution. In milk-ripe stage kernels are not present as a separate fraction since they get spread on the surface of other plant parts during chopping process.

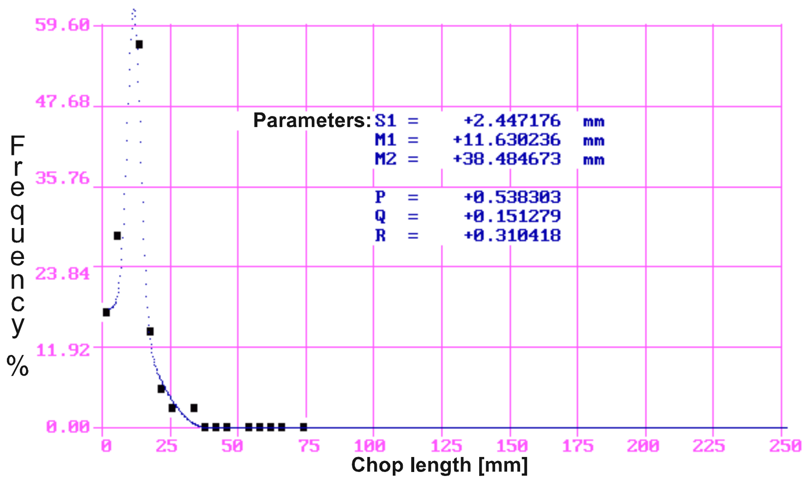

Fig.1: 6 parameter mathematical model developed for particle length histogram of milk-ripe silomaize chopped bulk

Legend:

M1 - Expected value of the normal distribution fraction

S1 - Scatter of the normal distribution fraction

M2 - Parameter of the parabolic distribution fraction

P - Proportion of the normal distribution

Q - Proportion of the uniform distribution

R - Proportion of the parabolic distribution

It is obvious according to these, that though the model presents the most accurate description among all known ones for a whole chopped bulk, it is most suitable for describing chopped bulk consisting only of stalk (Fig. 2).

The characteristic dimension for leaves is the length as well (Fig. 2), but the expected value of normal distribution (M2) is lower, while the scatter (S1) is higher than those of fitted to the histogram of stalk fraction of the same sample.

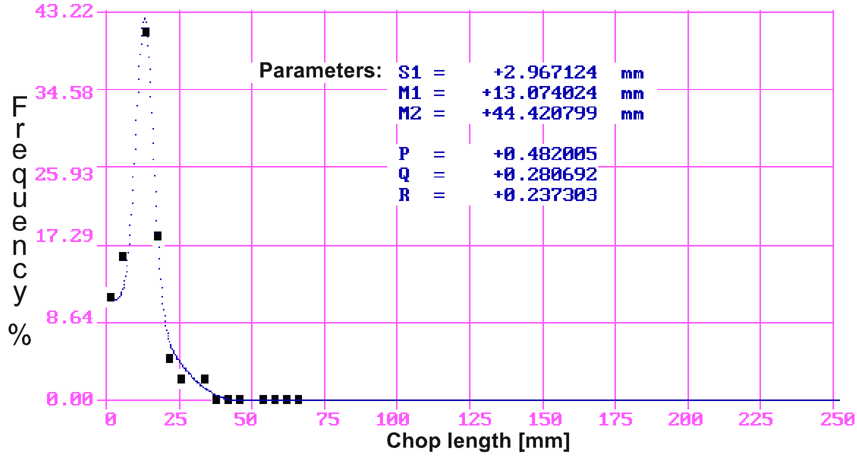

Fig. 2. Histogram-fitting to chopped maize stalks

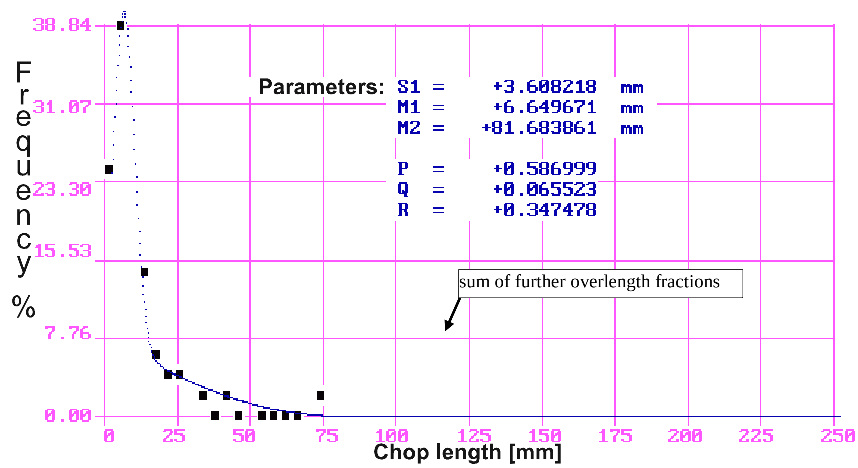

Fig. 3. Histogram-fitting to chopped maize leaves

This means that the grinding, dragging and creasing effect of chopping construction present themselves stronger in case of shorter leaves-fraction. Worn cutter-head knives or false gap may also cause non-perfect cut in thin leaves. Long plant fibres hang out and often link particles up. In Fig.4 it can be seen a microscopic view of a chopped particle made transparent by a special method developed by us. Bruises in the middle of the particle are obviously the sign of halving of the so called cut-frequency. Putting it simpler the maize leaf has been bent down during the cut and only the next cutterhead-knife could separate it. Consequently the particle under discussion has bruised in the middle and its length has doubled.

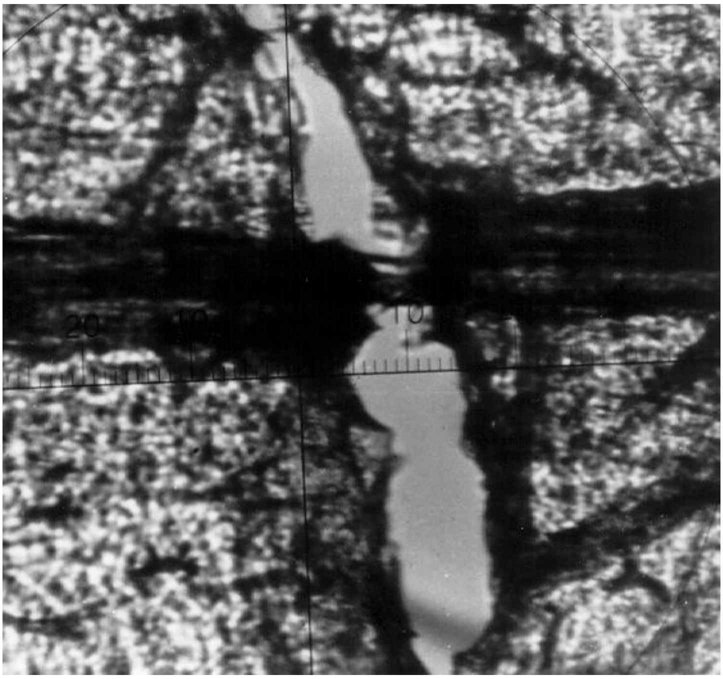

Fig. 4. Bruise in the middle of a leaf chaff
(Optics: 20/0.4 + Zeiss photo attachment MFP k 3.2:1 + opal filter. Time of exposition: 1/30s.)

2. Theoretical investigation of biomass burning process

In depth theoretical analyses of biomass burning was initiated by our research group due to the intensive application of such materials for energy production purposes [3]. At this phase model of wood has been elaborated. Adaptation of this theory to other products – based on biological and physical similarities – can be processed with no difficulties.

The yield of wood is about 10^{11} metric tons per year in the world. Cellulose and lignin are the two main constituents of the wood; both are complexes of great molecular mass. Cellulose is a polysaccharide; i.e. glucose molecules bonded together by bridges oxygen constitute it. The basic skeleton of the molecule is a six-membered oxygenian ring carrying hydroxyls. Its composition formula: $C_6H_{12}O_6$. When wood is heated, the so-called dry (or destructive) distillation takes place during which gases – hydrogen, carbon monoxide, methane and other light hydrocarbons – evolve from it. These together constitute wood-gas that – substituting it for natural gas – may be used as combustible for firing, and as fuel of gas engines driving electric generators. If all volatile components have left the wood, there is charcoal (similar to coke) remained which is chemically pure carbon in a great part. Its combustion takes place in the form of a heterogeneous (superficial) reaction. This reaction consists of the following phases in sequence:

- diffusion of oxygen from the ambient atmosphere to the surface of charcoal,
- chemisorption of oxygen on the surface of wood,
- reaction between carbon and oxygen atoms, producing carbon monoxide,
- desorption of carbon monoxide from the surface of wood,
- diffusion of carbon monoxide into the air,
- reaction of the carbon monoxide molecule with the oxygen of the air, producing carbon dioxide.

The rates of the above processes are very different, and greatly depend on temperature. For the temperature dependence of chemical reactions, Arrhenius's law is valid. It shows that the rate of chemical reaction is proportional to the function

$$e^{-\frac{W}{kT}} \tag{1}$$

in which W = activation energy, k = Boltzmann's constant, and T = absolute temperature.

Hence a general empirical rule arises: every increase of 8 ºC in temperature doubles the rate of chemical reactions.

The combustion of wood is an exothermic reaction. For the combustion process to be self-sustainable, it is necessary that the heat evolving in the course of the reaction and the heat leaving the combustion space must be in equilibrium. According to the above, it needs a minimum, so-called ignition temperature; this is 225 ºC for wood. Since the combustion of wood is a heterogeneous reaction, the rate of combustion is determined by the effective – for the chemical reaction: dominant – surface area of the wood developed in the combustion space.

Therefore, if a high heat output is required, chips are made from the wood and those shall be used as fuel. For an actual chips-size distribution, the slowest one of the above six processes determines the rate of the overall combustion process. According to investigations, above 1000 ºC, this one is the diffusion process [4]. Two limits should be set for the size distribution of the chips. One of these is that even the smallest size must be greater than the size of the grate slots (air spaces) and the other – even the chip of largest size should completely burn out in the combustion space, at the actual stoker (grate) speed.

It is also clear that, in the case of fulfilment of these two limiting conditions, different heat outputs belong to every each chips-size distribution, at actual grate (stoker) speeds and fuel feeding of actual volumetric flow rates. Consequently, there is a possibility of developing an optimal size distribution, and the chipping technology producing it. The long-term objective of the present research is to clarify these two issues.

2.1. Firing-technological relationships in the case of wood burning

In the following part, the firing relationships elaborated for coal- and gas-fired boilers [5] are adapted to the case of wood burning. It is doable simply with full knowledge of the exact chemical composition of the firewood determinant for the combustion process. For lack of the actual composition, the following quite good, preliminary orientating data of the composition of wood may be used to a first approximation: 82 to 87 % carbon (C), 11 to 14 % hydrogen (H), 0.1 to 5.5 % sulphur (S), 0.1 to 1.5 % nitrogen (N) and 0.1 to 4.5 % oxygen (O). With knowledge of the composition, the heating value of the firewood can be determined:

$$W_H = 39{,}210C + 117{,}670(H - \frac{O}{8}) + 906S - 2460n \quad kJ/kg, \tag{2}$$

where n = moisture content of wood in mass fraction (part per mass). Experimentally, the precise determination of the fuel value can be effected by a calorimetric bomb.

The theoretical air volume required for perfect combustion can be calculated from the following relationship:

$$V_{Air,0} = 8.89C + 26.7(H - \frac{O}{8}) + 3.33S \quad std.m^3/kg. \tag{3}$$

The theoretical quantity of evolved dry smoke gas (fume) can be determined by the formula

$$V_{Fume,dry} = 8.89C + 21.1(H - \frac{O}{8}) + 3.33S + 0.796N \quad std.m^3 / kg, \tag{4}$$

where N = mass fraction of the nitrogen. Considering that the combustion always takes place with some air excess, and that the fume contains some water vapour too, the actual (true) quantity of fume can be calculated in the form

$$V_{Fume} = \frac{1.867C}{k} + \frac{9H + n}{0.804} + 3.33S + 0.796N \quad std.m^3 / kg \tag{5}$$

where k = CO2 content of fume (or smoke gas). For controlling the combustion process, the carbon-dioxide content of the fume has to be detected; accordingly, the variable k in the above relationship is a measured quantity (detected value). If not the carbon dioxide but the oxygen content of the fume is detected, k can be determined through the following relationship:

$$k = m \frac{21}{21 - O_2} \tag{6}$$

Here m is the air excess factor. Using these, the theoretic combustion temperature can be determined:

$$t_{combustion} = t_{Air} + \frac{W_H}{V_{Fume} c_p}, \tag{7}$$

where cp = isopiestic heat of the fume. If the boiler produces hot water or steam, the determination of the mass flow rate of firewood is possible from the mass flow rate Imass,water or Imass,steam, and the heat content of the produced hot water or steam, respectively:

$$I_{mass} = \begin{cases} I_{mass,water} \dfrac{i_{hot\,water} - i_{feedwater}}{W_H \eta} \\ I_{mass,steam} \dfrac{i_{steam} - i_{feedwater}}{W_H \eta} \end{cases} . \tag{8}$$

Here ihot water, isteam and ifeedwater are the heat contents (enthalpies) of hot water, steam and boiler feed water, respectively, and η is the efficiency of heat transfer. For determination of the travelling velocity of grate (stoker) as well as the control-technical parameters of the boiler, it is necessary to know the combustion rate. Additionally, the effect of the size distribution of wood chips, too, will arise in connection with the combustion velocity; and this is to be discussed below.

2.2. Similitude-theoretical description of the combustion process

The exact basic equations of combustion process, including the stoichiometric equations of the chemical reactions as well, are known. The main problem is that that these latter equations are true of the overall chemical reactions only, and express nothing about the intermediate reaction stages and the intermediate reaction products. Thence the theoretical analysis of the combustion process in a more complicated case is impossible; nothing remains but the approach of similitude theory.

- The similarity-criterion numbers can be gained from the exact equations. These are
- Reynolds's equation of turbulent (or eddy) flow,
- Fick's equation extended with a source term of the turbulent diffusion for every each chemical component,
- Fourier's equation extended with a source term of the apparent (turbulent) conduction of heat,
- stoichiometric equations of the heterogeneous reactions,
- Langmuir's or Freundlich's equations of chemisorption of active components,
- equations related to the rate of chemical reactions, with Arrhenius's laws concerning the rate constants,
- constitutive equations concerning reaction heat.

The criterion numbers determinable from the equations [6] are as follows: the Reynolds number (Re), the Nusselt number of the heat transfer (Nu), the Nusselt number of the material (mass) transfer (Nu'), the Stanton numbers concerning the heat and the mass transfer (St, St'), and the Schmidt number (Sc). In the following part, only the stationary combustion process is analysed since this is the most important in respect of the practice.

Let the concentration of the reacting matter on the wood-gas phase boundary be c', and in the gas space – c. In the course of the mass-transfer process, the concentration flow incoming through diffusion on the reaction surface:

$$I = \beta(c - c'),\tag{9}$$

where β = mass-transfer number. During combustion, the reacting matter with the oxygen of air constitutes a reaction product; accordingly, the molecules of the reacting matter have a source term in Fick's diffusion equation existing for the concentration due to the combustion. The intensity of the source term is dependent on the reaction rate. The heat power (or output) produced through combustion depends on the reaction rate as well. According to the principle of conservation of matter, it can be stated that

$$I = \beta(c - c') = P,\tag{10}$$

where P = intensity of production. The production intensity is a function of the concentration of the reacting materials, c', i.e.

$$I = \beta(c - c') = P = g(c').\tag{11}$$

For simplicity, the overall reaction taking place during combustion of wood will be approximated with a first-order reaction therefore the function g(c') is linear. Accordingly the above equation can be written down in the form

$$\beta(c - c') = Kc'\tag{12}$$

where K = rate of reaction, in respect of which the Arrhenius equation holds:

$$K = Ze^{-\frac{W}{RT}},\tag{13}$$

Here Z is a constant characterizing the combustion process which is conditioned by the size distribution of wood chips in this case; R = gas constant, T = temperature, and W = activating energy of the reaction. From equation (12), the concentration c' can be exterminated due so, in the course of the experimental work, the constitutive equation

$$I = K^* c, \quad K^* = \frac{K\beta}{K + \beta}\tag{14}$$

should be determined in which the mass transfer co-efficient can be given with the Nusselt number for laminar flow, or with the Stanton number for turbulent flow [1]:

$$\beta = \begin{cases} Nu' D / L & \text{for laminar flow} \\ St' V & \text{for turbulent (eddy) flow} \end{cases} \tag{15}$$

Here D = diffusion constant, L = characteristic linear dimension and V = characteristic flow rate of the gas. In respect of these criterion numbers, the equations

$$Nu' = f(\mathrm{Re}, Sc), \quad St' = f(\mathrm{Re}, Sc), \tag{16}$$

that can be determined in empirical way, hold.

Fortunately, the Nusselt number can be considered as constant for laminar flow and, as to the Stanton number, it can be taken to be constant, too, for highly turbulent flows so the experimental work will be simplified to determining two constant quantities. It can be seen from Arrhenius's law (13) that the reaction rate is greatly conditioned by the temperature. Consequently, it is important to determine the temperature conditions more exactly as it has been done in section two. Thereto the heat-transfer co-efficient should be determined which, by analogy of the above, is as follows:

$$\alpha = \begin{cases} Nu D / L & \text{for laminar flow} \\ St V & \text{for turbulent (eddy) flow} \end{cases} \tag{17}$$

The same applies to the Nusselt and the Stanton numbers related to the heat transfer as that has been told in connection with equation (15). With the knowledge of the heat-transfer co-efficient, the Fourier equation can be applied to the gas phases of the combustion space:

$$\rho c_p \frac{dT}{dt} = \alpha \, \Delta T + q \,, \tag{18}$$

where $\frac{dT}{dt}$ is the substantial time derivative and, as to the source term q, it describes the heat power evolved in a unit of volume during the reaction. This combustion chemical reaction is conditioned by the production intensity P and the heat effect Q of the reaction.

In accordance with equations (11) and (14), it can be written down that

$$q = QP = QK^{*}c = Q\frac{K\beta}{K+\beta}c \tag{19}$$

At last, taking Arrhenius's law (13) into consideration, the final form of the equation of heat conduction is given:

$$\rho c_p \frac{dT}{dt} = \alpha\,\Delta T + Q\frac{\beta Z e^{-\frac{W}{kT}}}{\beta + Z e^{-\frac{W}{kT}}}\,, \tag{20}$$

Let us change over to the local time derivative in the equation [4] then it will be given that

$$\frac{\partial(\rho c_p T)}{\partial t} + div(\rho c_p T\overline{w} - \alpha\ grad\ T) = Q\frac{\beta Z e^{-\frac{W}{kT}}}{\beta + Z e^{-\frac{W}{kT}}}\,, \tag{21}$$

where $\overline{w}$ is the velocity of the flow.

Since, practically, the stationary combustion process is of importance, only the case of the stationary heat conduction is studied!

From (20), the equation

$$div(\rho c_p T\overline{w} - \alpha\ grad\ T) = Q\frac{\beta Z e^{-\frac{W}{kT}}}{\beta + Z e^{-\frac{W}{kT}}}\,, \tag{22}$$

is given for that.

The further similarity criterion numbers necessary for planning the scale-model experiments can be determined from this equation.

The similarity criterion numbers come of the condition that the above equation must remain invariant against a collineatory transformation of similitude.

From this further three (Peclet's, Damköhler's and Arrhenius's) similarity criterion numbers

$$Pe = \frac{Lw}{\alpha}, \quad Da = \frac{Lc\beta ZQ}{(\beta + Z)Tw}, \quad Ar = \frac{W}{T}, \tag{23}$$

are given where L is the characteristic linear dimension.

These scale-model experiments can be applied to an industrial-size boiler if the above similarity numbers of the scale model and the boiler are equal to each other.

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COMBUSTION-DYNAMIC QUALIFICATION OF CHOPPED FUEL-WOOD STRUCTURES

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Abstract

A combustion-dynamic investigations were carried out by derivatographic examinations with woody base material chips as a partial topic of the NKTH-OTKA K-68103 research program. With artificial mix structures, we have looked for such a dominant combination that determines the combustive parameters of the congeries. As the result of our experiments we proved that the intensity of the gasification of samples and the burning of the residue charcoal phase is proportional to the size of the chips.

Keywords

biomass, biomass firing, combustion, particle size distribution, lab derivatography

1. Introduction

One of the results of the research program "Optimizing and Modelling of Plant Congeries Structures Prepared for Non-Food Use" supported by the NKTH-OTKA (*National Scientific Research Basic Programmes*) is presented in this lecture. The actually selected partial task here is to determine the optimum composition of chips congeries – the most suitable one for the direct caloric utilization of biomass.

Both research centres (the SZIE Faculty of Mechanical Engineering and the VM National Institute of Agricultural Engineering) taking part in the programme have a several-decade good practice – independently and together as well – in modelling and evaluation of structural composition of vegetable masses for animal feeding. Also inventions and patents were born in the topic; they had been focused on the correct description of the congeries structure, the modelling and determining of the parameters based on its mechanical-viscoelastic behaviour, decreasing of energy demand of production and optimization of feed utilization.

In an earlier article, authors have already presented that the combustion takes place in the form of a surface chemical reaction. From this point of view, it is advantageous to cut the biomass to the possible minimum size. However, in terms of boilers, the short reaction time is not evidently an optimum. Besides the burning properties, it must be considered as well that the cost of chopped material production is also a decisive view-point; the cost exponentially increases with the degree of comminution.

2. Materials and methods

The international research trends on biomass firing can be briefly summarized as it follows:

- The fundamental researches are focused on the chemical description of the combustion process and the measuring and comparing of the caloric values of biomass materials and their mixtures.
- The applied researches aim at the determining of the size ranges of the chips or chops burned in the different boiler types.

In the first case, the experiments are carried out with samples of some grams so the post-chopping (further chopping) of the material cannot be avoided. These are integrating type measurements and they give no information about the course (time function) of the process and the effect of the original structures.

In the second case, the biomass congeries is optimized according to the requirements of the boiler type where the combustion characteristic is only a partial aspect. For example, for the chain-grate boilers, the chain pitch determines the minimum size of chips and the chain speed has to be set to the value at which even the biggest element of the congeries shall burn out. Accordingly, the homogeneous fuel would be the optimum case.

With the fluid boilers, the comminution degree of the fuel has both an upper and a lower limit. The risk of the dust explosion means the lower limit and the melting risk of a fluid-bed component (mostly silica sand) – the upper one. According to the experiments in the Research Institute of Electric Power Industry (*VEIKI*), the congeries with particles smaller than 1 mm flared up and burned out at an explosion-like rate that produced intensive pressure waves even with a little mass. The single chopped wood pieces, after throwing them on the fluid bed of temperature of 800 to 900 ºC, were gasified quickly and the developed volatile matter burned out in the combustion chamber in some seconds. The remained coke pieces, moving in the layer, burned for several minutes. In the case of continuous firing with wood chips of fraction size above 50 mm, the coke pieces were accumulated in the layer and, under the effect of the released heat amount, the layer material will be overheated in a short time. In the experimental device, the layer temperature increased by 400 ºC in 5 minutes and the sand bed melted. Accordingly, with the fluid-bed firing, the particle size of the fuel has to be kept between narrow limits that can be provided by closed-circuit grinding or by screening separation of the fuel fractions.

Even when the sample can be burned out in the boiler without after-chopping, the results of the caloric measurement qualify rather the draught conditions of the boiler and the efficiency of the heat exchanger than the fuel. Accordingly, in the actual measurements, we rejected the burning tests in boiler. The heat values of the used materials were determined by calorimetric-bomb tests and the effects of structure was investigated by the derivatography process. The latter method originally serves for measuring the volatile and ash content of the fuels. Its device is the programme-controlled burning furnace connected with a digital scale of which parameters are defined by the relevant standards. With the help of the process, the mass decreasing of a fuel of unknown composition can be continuously measured and recorded as a function of programmed time zones. Even a sample of 300 g can be put in the furnace so the after-chopping is omissible.

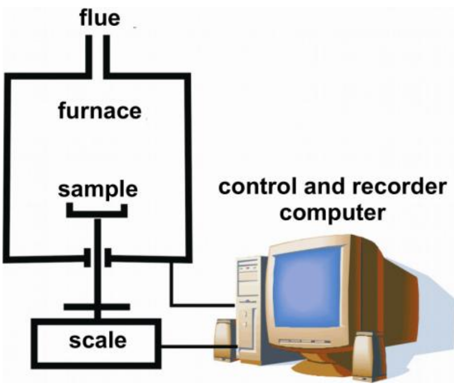

Fig. 1. Derivatographic lab furnace

According to our experiences, the numerical particle size distribution models of the congeries made by grinding or chopping give a suitable result for identification only if the sampling as well as the separation of the samples into size fractions is carried out according to the method defined in the process description or the standard. If the same sample is separated into different fraction ranges, the shape of the regression functions remains the same but the parameter values will change. Consequently, the identification of the congeries, the repeatability of the experiments and the comparability of the results will get impossible. During the past twenty years several researchers have had a try at elaborating a suitable method based on the digital image processing to be substituted for the manual structure analysis. According to the results of our research team, this method today still can be used for only estimations due to the overlaps and the distorting effect of sample elements oriented in space. However, with the knowledge of the estimation confidence, this accuracy seems to be acceptable for an approximate structure diagnostics or as a control input for the firing process.

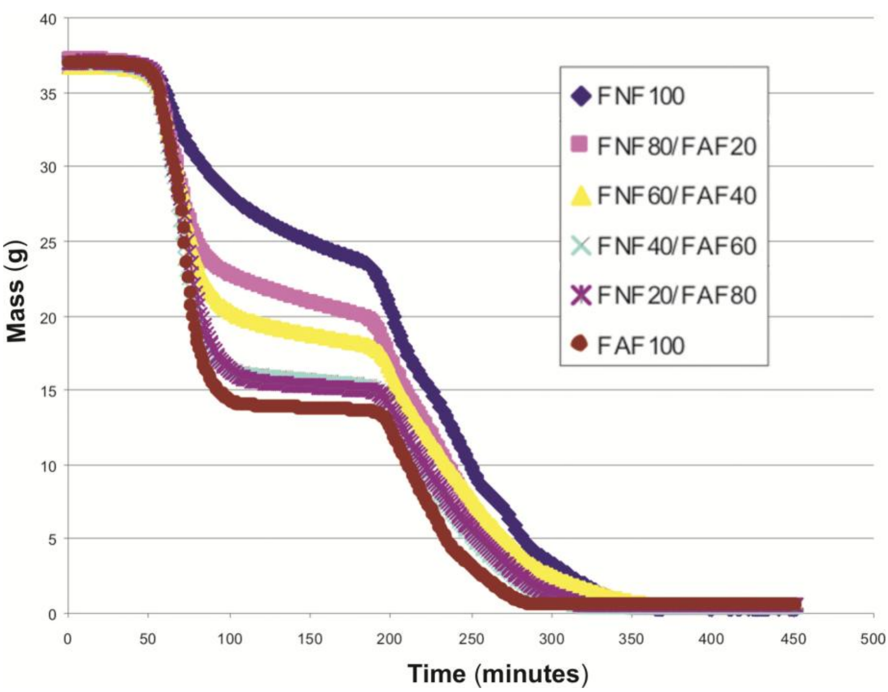

Fig. 2. Mass-change measurement results of derivatographic tests with willow chips
(FNF = 40-mm long-cut fraction, FAF = 5-mm short-cut fraction; figures mean %-ratios)

During the laboratory tests, artificial structures were used because of the above described uncertainties. Homogeneous samples and inhomogeneous samples made of different mixtures of two uniform bulks were tested by the method of derivatography. The elements of the two fuels composing the latter sample mixtures were significantly different in their lengths (and proportionally in their free surface area values). From the fuel-type agricultural biomass plants, the energy willow (*Salix*) was chosen which can be chopped by self-propelled ensilage harvesters. The particle size of the homogeneous samples was selected to 5, 10, 20, 30, and 40 mm; the inhomogeneous samples were the mixtures of 5 and 40-mm elements with different ratios.

3. Results

According to the standard CEN/TS 14775:2004 elaborated for lignocelluloses, the sample exsiccates in the first phase of 105 ºC and then, between 250 and 550 ºC, the dry distillation of the biomass takes place. During this, the volatile components (hydrogen, nitrogen, sulphur, oxygen, carbon monoxide, methane and other light hydrocarbons forming together the wood gas) are released from the solid and the coke-like charcoal remains – a chemically highly pure carbon. Finally between 550 and 880 ºC, the charcoal burns out and only some-percent ash remains from the sample.

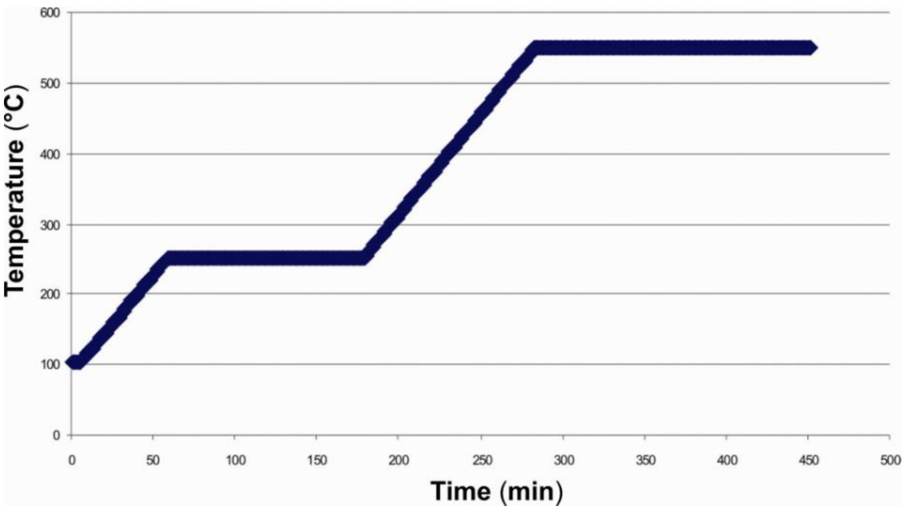

Fig. 3. Temperature of the combustion chamber in the section of test program shown in Fig. 2

It has been established that the test by the relevant standard is only suitable in cases with powdered samples so a new test methodology had to be developed and applied for the structured samples (not chopped further). The theoretical ignition temperature of the wood is 610 ºC but, in the case of the two-year willow samples according the experiences, the full gasification took place at

250 ºC and the combustible residue burns to ash at 550 ºC. It can be seen in Figure 2 that, with the single particle size exceeding 5 mm, the necessary time of the chemical reaction during the dry distillation and the complete burning-out of the charcoal (where the intensity of oxygen diffusion determines the reaction rate) requires a longer holding period at a temperature than that defined in the standard.

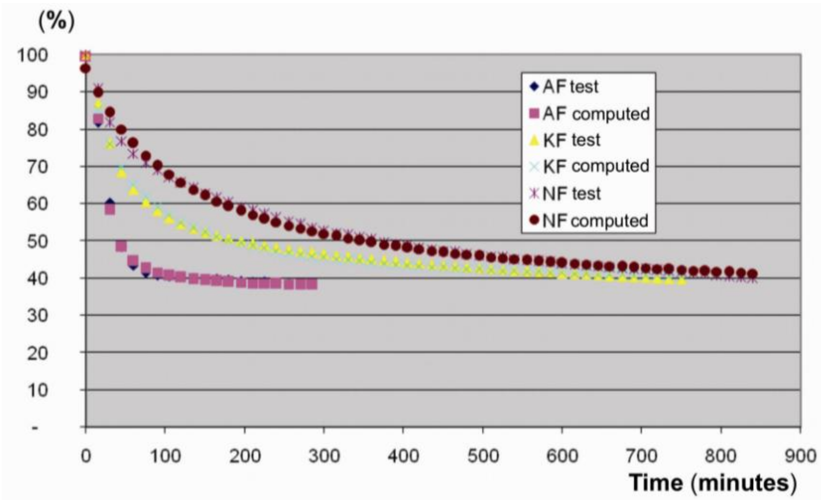

Fig. 4. Mass lost of energy willow (Salix) samples at 250 ºC
(AF = 5 mm, KF = 20 mm, NF = 40 mm)

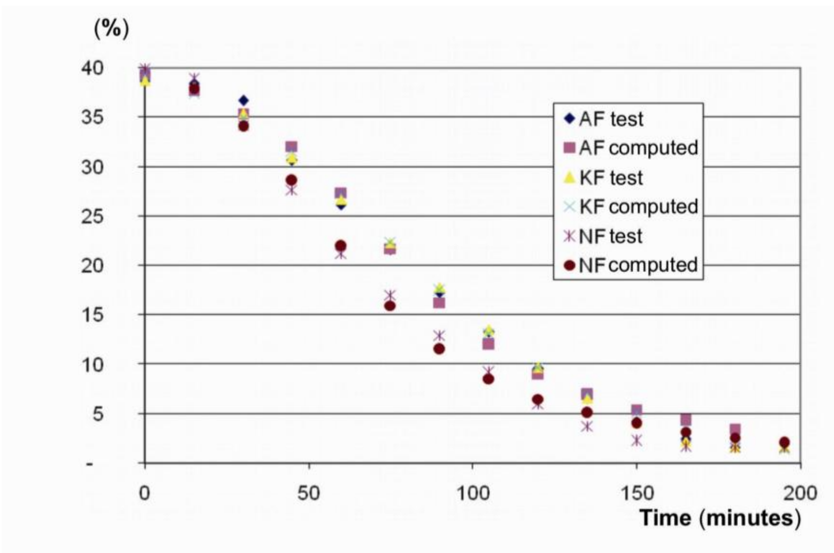

Figure 5: Mass lost of energy willow (Salix) samples at 550 ºC

For the following phase, the tests were divided into two parts. The dry distillation was carried out in a separate test and then the charcoal residues were burned out to ash under the same conditions. Increasing the holding time at the temperature of 250 ºC up to twelve hours, even the 40-mm sample lost its total volatile content including the chemical reaction products as well (Figure 4).

The gasification and the burning-out processes indicate different characters because of the different time demands but the decrease in mass (m) vs. time (t) functions can be approached by the following arc tangent relationship in both cases:

$$m(t) = a + b\frac{arctg(\frac{t-c}{d} + \frac{\pi}{2})}{\pi}$$

For the two-year energy willow fuel, the co-efficient values are as it included in Table 1.

Table 1. Calculated parameters of the mass decrease vs. time function

	AF = 5 mm		KF = 20 mm		NF = 40 mm	
°C	250	550	250	550	250	550
a	36.99	–2.35	36.61	–6.21	32.97	–2.38
b	77.39	49.89	963.56	56.51	1219.45	53
c	18.91	72.72	–48.11	76.07	–126.05	55.17
d	–13	–41.02	–10.1	–53.56	–20.79	–37.62
r^2	0.99	0.99	0.99	0.99	0.99	0.99

The physical meaning of co-efficient "b", "c" and "d" has not been known yet; the parameter "a" shows the per-cent value of the residue mass at the end of the process. Of course, this must not be a negative value but during the measurement the value of mass decreases by a magnitude order and the measuring accuracy rated by the manufacturer of instrument cannot be sustained until the end of experiment. At the same time the 5-% error limit does not require the repetition of the regression with corrected data.

4. Summary

In this article, we reviewed the results of the combustion-dynamic investigation of woody base material chips as a partial topic of a basic research program. Derivatographic examinations were carried out on artificial structures prepared in laboratory conditions. With the help of the artificial mix structures we have looked for such signs which indicate the combination dominance determining the combustive parameters of the congeries. As the result of our experiments, we proved that the intensity of the gasification of samples and the burning of the residue charcoal phase is proportional to the size of the chips. We elaborated the mathematical model of the mass decrease of the samples. Both process parts can be well characterized by a four-parameter function and we determined these parameters for the energy willow fuel.

Acknowledgements

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Combustion-Dinamics of Energy Purpose Biomass

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Abstract

This article presents a method, which, irrespective of the blast conditions of the furnaces, can investigate the combustion process of the ligneous chips congeries. With the help of homogeneous and artificial mix structures, the authors tentatively demonstrate, that the combustion speed of wood-chips is not depend on only the surface area of sample (size of pieces), but the order of the parts of pile too. Consequently: the combustion process will be optimum in the case of a purpose structure with suitable size distribution only.

Keywords

wood-chips, combustion process, optimization

1. Introduction

With the full knowledge of the chemical composition of the fuels, their combustion heat can be calculated easily by Dulong's formula. This method takes into consideration that a certain part of the fuel material is originally already oxidized in organic compounds. After deducting the evaporation heat of the original water content of the material, the calorific value can be determined. If the chemical composition of the material is unknown, the combustion value (otherwise gross calorific value) of the material can be experimentally measured by a calorimetric-bomb test as well. However, in this case, the fuel (or heating) value is only estimated; the moisture content of the sample can be determined by the drying-box test but the exact calculation requires the value of the hydrogen content of material, too. Both the combustion heat and the heating value mean the maximum withdrawn energy from the unit of fuel during its perfect burning; accordingly, it supposes the use of ideal furnaces (boilers) with no loss. The so-called condensation boilers utilizing the total combustion-heat recover the heat content of the vapour in the off-gas. Their theoretical efficiency referred to the fuel heating value may achieve the value 108.8 %. Nowadays these types are widely used in gas-fired systems but they have not spread in the multi-fuel furnace technology yet because of the high sulphur content of the solid fuels, more exactly the formed aggressive acidic condensates from the off-gas.

When burning wood or other grown biomass plants, the complete oxidation cannot take place alone – it requires especial technical and firing requirements to be fulfilled. The necessary volume of air (oxygen) must be provided in more stages – in the form of primary, secondary and (maybe) tertiary air supply at the different points of the combustion space. Since the hot wood-gas hardly intermixes with the cold air, practically an air excess of 70% ($\lambda = 1.7$) is required to provide the stoichiometric combustion-gas to combustion-air ratio. The design of the combustion chamber of the boiler and the quantitative control of the induction of combustion air basically influences the utilization efficiency of the solid fuel matter. The dual goal of the control is:

1. the power control for matching the heat performance of the boiler with the power demand of user and
2. the control of the combustion process for decreasing the harmful-matter content of the flue gas

Since the control takes place by throttling the combustion air flow, the rated efficiency of 72 to 86 % given by the boiler manufacturer can be referred only to the planned heat power and even this ideal value is lower than the 92-% efficiency of the traditional gas boilers – not to mention the achievable value of the condensation technique.

The firing control must provide such a combustion quality in all boiler-load states which ensures a low polluting-matter emission. Beside the combustion-air control, the application of the feed-back of flue-gas as well as the mechanical fuel feeding helps to perform this goal. However, the required solid fuel must be homogeneous as to its material, particle-size composition, moisture content and heating value.

Practically, the ground or chopped fuels are considered as homogeneous matters. Amongst the wood-chips firing large devices, the control of the fluid boilers is the simplest. The boilers with underfeed or overfeed firing are more sensitive to the particle-size distribution of the chips mass due to the spreader stoker.

2. Materials and Methods

The international trends of researches on biomass firing can be briefly summarized as follows:

- The fundamental researches are focused on the chemical description of the combustion process, the measurement and comparison of the calorific values of biomass fuels and their mixtures.
- The applied researches concentrate on determining the size range of fuel chips to be burned in the different boiler (furnace) types.

In the first case, the experiments are carried out with samples of some grams so the after-grinding of the bulk – in this way changing the combustion properties – is unavoidable. These types of measurement have an integrating effect; accordingly, they do not provide information about the course of the process and the effect of the original structure.

In the second case, the biomass congeries is optimized according to the demands of the boiler (furnace) type. Taking the combustion properties into consideration is only one of the points of view in the optimization. With a chain-grate boiler type, for example, the grate pitch limits the minimum size of the fuel chips.

Consequently, it can be established that both the calorimetric tests and the firing experiments carried out in in-plant conditions are insufficient for qualifying fuel chips. The condition of the reproducibility is the use of an independent laboratory measuring system from the blast patterns of the actual boilers.

This is why the effect of the structure of the fuel congeries was analysed by the method of derivatography. Originally, this technique was elaborated for measuring the volatile and ash content of fuels. The test device is a program-controlled burning furnace with standard parameters, connected with a digital scale. With the help of the test process, the mass decrease of a fuel substance with unknown composition can be continuously measured and recorded as a function of the programmed temperature zones and time. Even a 300-g sample can be put in the furnace so the after-grinding or chopping is not necessary. In accordance with the standard CEN/TS 14775:2004 elaborated for lignocelluloses, the sample desiccates in the first period of 105 °C and then, between 250 and 550 °C, the dry distillation of the biomass takes place. In the course of this, volatile matters (hydrogen, nitrogen, sulphur, oxygen, carbon monoxide, methane and other light hydrocarbons – together composing wood-gas) as chemical reaction products leave the sample and a certain amount of charcoal (similar to the coke) remains and its dominant part is chemically pure coal. Finally the charcoal burns between 550 and 850°C and only some percents of ash remains from the sample. Accordingly, the processes of drying-degasification-burning are carried out in three temperature stages, and drawing apart in the time. With this method, an accidental explosion caused by an intensive gasification can be prevented but it cannot be considered a single-variable process because the combustion takes place mainly during the heating-up. Consequently, the standard test is suitable only in part to answer the questions of the authors. For eliminating the transient processes, it is reasonable to place the sample in the burning space of the preheated furnace.

Fig. 1. The modified derivatograph

In order to protect the measuring instrument of the accredited laboratory, a new (and cheaper) device had to be constructed. Such an annular furnace was purchased where the heating coils were built in the sidewall of the device so the top cover could be bored through and, by a drop-in device mounted on the cover, the sample could be inserted into the preheated furnace. With the process of derivatography because of the small amount of sample, instead of the weight of the complete furnace, the weight of the incinerator pot has to be directly measured. It was solved by a precision scale mounted under the furnace, equipped with transmission elements made of heat-resistant ceramics. The method of measurement was as follows: The prepared, photographed and documented sample was dropped in the preheated furnace. The scale was tared and the measurement was carried out up to the mass constancy (ash content). Without emptying the incinerator pot, after dropping the following sample in, the scale was tared again. So the furnace did not cool down and, utilizing its thermal inertia, a large amount of data could be collected in a short time. Against the recommendation of the standard, the temperature of the furnace was chosen to 450 °C. Several preliminary experiments were carried out before selecting the temperature value during which it was established that the full combustion of the sample took place at this temperature and, at the same time, the explosion of the vapour from the remnant moisture content of the air-dry sample and wood-gas developed by a quick degasification should not be expected.

The practice consider the fuel chips as homogeneous mass but, according to the experiences in this research, the congeries gained by grinding or chopping, as to their size distribution, are not quite homogeneous at all; nor the experiments are reproducible or the test results – comparable. During the laboratory tests artificial structures were mainly used because of the above described circumstances. In this article, those experiments selected from the others are presented which carried out on showing the effect of the comminution degree of the congeries, the composition of the mixture bulks upon the combustion characteristics. For these, two sample sets with different artificial structures were prepared. Their common property was that the inhomogeneity in material quality of the congeries components was precluded. The wood dowels available in do-it-yourself stores were found as the most uniform fuel material. These are made of birch duramen with an acceptable size tolerance from the view point of the tests. The congeries structure used in the investigations was made by re-cutting and mixing together the dowels. The samples containing also bigger pieces were manufactured from softwood roof battens. As the samples were cut from the same batten, the combustion properties can be considered as approximately equal here as well.

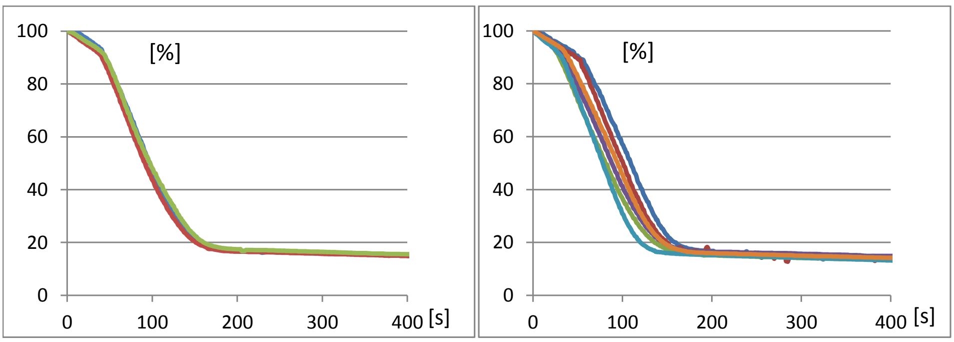
3. Results and conclusions

Authors searched for the reply to two basic questions with the help of the above presented experiments of derivatography:

1. Is there an optimal congeries composition existing in terms of firing? With the help of the artificial structures, authors searched for such signs indicating the dominance of composition which basically determine the combustion parameters of the congeries.

2. The combustion takes place in the form of surface-reaction so the fuel material must be ground (chopped or cut) to the possible finest particles. However, the compaction of the extremely over-ground fuel particles can cause also an air shortage in the firing equipment. Consequently, the second question can be stated in the following way: Is there an optimum existing below which it is already not expedient to decrease the size of fuel particles?

For examining the ideal congeries composition, sample masses composed of wood dowels re-cut at different degrees were selected. It was established that the theoretically predicted relationship between the comminution degree and the dynamics of combustion is valid. However, with the mixture structures, the spatial order of the particles basically influences the combustion speed. Mixing 20 to 25 % fuel particles with the size deviating even by a magnitude order in the bulk will not change the combustion characteristics of the congeries yet; the experiment takes place in the expected way according to the dominant size fraction. After mixing 50 % small fraction in the bulk, the course of the combustion process cannot be predicted.



20 % small fraction   50 % small fraction

Fig. 2. Derivatograms of wood dowels

During the repetition of the experiments, the results can be found anywhere between the combustion curves of the two fractions. This means that the speed of the mass decrease taking place in the course of the combustion also depends on the free surface area formed due to the stochastically ordered particles of the congeries – and not only on the total surface area of the bulk. This is denominated as channelling effect in the professional editions of English language. Along the ordered flowing paths formed in the congeries, the propagation speed of the flame front increases. The unpredictable behaviour of the fuel mixture is caused by the ventilating cavity system which is clogged when the congeries collapses but then newly formed randomly along another pathway. In a homogeneous congeries, the lengths of the clogging and the developing channels are not significantly different so the data of the repeated experiments show slight deviations. For demonstrating this observation, further experiments were carried in which the fuel particles were arranged in a wire net in such a way that the congeries could keep this order during the full combustion. With the congeries prepared in this way, the reproducibility of the combustion experiment significantly improved.

When determining the optimum of comminution degree, besides the homogeneity of the fuel material, just the mentioned channelling effect was employed in reducing the impact of the random arrangement of congeries. The fuel samples were prepared by lengthwise splitting wood prisms of 40 g mass. So practically the channelling was increased up to the degree at which the increase of the free surface area already caused no change in the dynamics of mass decreasing. During the investigation the main question was whether such an optimum exists or no rather than determining the optimum particle size by measurement. By the experience of authors, the optimum exists – already no significant difference was found between the derivatograms of the sample prism split into 16 pieces and the sample split into 35 pieces.

Fig. 3. Wood towels sample, and ash in the cage

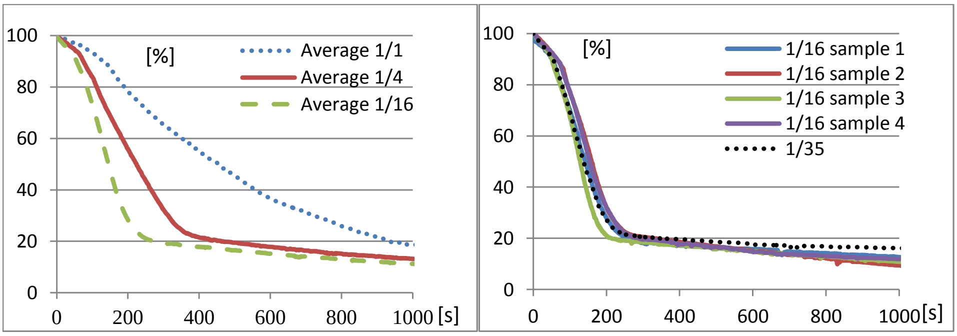


Fig. 4. Derivatograms of splitting wood prisms
(Specific surface of samples 1/1 = 3,4 cm^2/g, 1/4 = 6,1 cm^2/g, 1/16 = 11,5 cm^2/g)

The degasification and the burning process, due to the deviating time demands, might indicate different characters but the functions of mass decrease (m) vs. time (t) – even with the single-step process taking place by applying the sample-drop-in device – can be approached by the arc-tangent function introduced earlier by authors (Bense et al., 2009).

The regression functions and the quality factors of curve-fitting have not been shown in the figures since the numerical indication of the parameters does not provide essential extra information for better understanding of the processes.

Acknowledgements

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HARVESTING SILAGE MAIZE FOR NEEDS OF DAIRY COWS AND/OR NEEDS OF BIOGAS FACILITIES

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Hungarian Institute of Agricultural Engineering

Abstract

Maize silage is an important component of the dairy feed which can satisfy the annual fodder demand but as chemical energy storage material, the maize silage can utilize as a raw material of biogas plants. The daily feed dose of dairy cows is necessary to prepare with circumspection, considering the chopping length as well as the adequate quality and quantity of the silage and hay. The usage of maize silage gives high biogas yield that can be used for electricity and heat production in co-generation unit. The biogas yield depends also on the quantity of the substrate and the chopping length of the maize silage. The aim of our work is to provide current information: - about the most appropriate chopping length of silage maize for needs of dairy cows and/or needs of biogas plants. Maize is harvested by self propelled harvesters. According to measurements of our institute (MGI) the throughput and the specific fuel consumption of self propelled harvesters (Class, John Deere and New Holland) were evaluated in case of different chopping length.

Key words

biogas, maize, chopping length, self propelled harvester, dairy cow

1. Introduction

There are mainly four production phases of biogas production (phase I. – IV) and three phases of silage production for cows (phase I. – III) from maize.

Production phase I. is the biomass production. When maize is grown on the field, location, climate and maize variety are important. In phase II. (harvest, conservation and supply) methane yield can be influenced by choosing the harvesting time, harvesting and conservation technology, and by possibly applying additives, and by choosing the chop length (Bense et al, 2007). In phase III: chopped maize is fermented. In phase IV. energy in the organic substrates is transformed to methane energy in the biogas (Fig. 1), (Chynoweth, 2004).

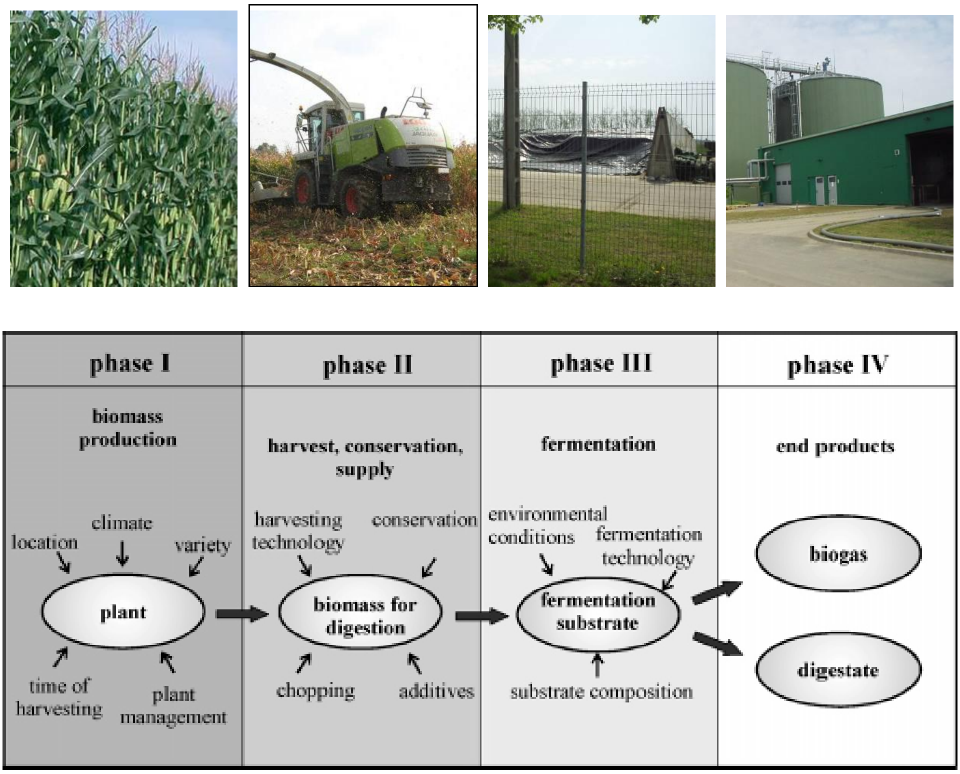

Fig. 1. Influences on biogas production from maize along IV different production phases (Amon et al, 2001)

1.1. Maize chopping for needs of biogas facilities: The Chop length (substrate size reduction) is one of the most important key criteria for the preparation of fermentation substrate (Balsari et al, 1983). Optimum particle size for silo maize is 5 mm theoretical chop length (range 4 - 8 mm) (Fig. 2). This recommendation provides the following benefits in the silo in phase III.: (a) potential for optimum compaction,(b) reduced fermentation gas losses,(c) cell breakdown/surface enlargement and(d) minimal energy losses (Schaumann, 2006).

This recommendation provides the following benefits in the biogas fermentor in phase IV.: **(i)** faster substrate breakdown,(ii) increased degree of breakdown,(iii) improved stirring properties and (iv) reduced flotation layer (Pazsiczki et al, 2010, Schaumann, 2006).

An important question whether the chop lengths at different recommended values lead to higher diesel fuel consumption during harvesting?

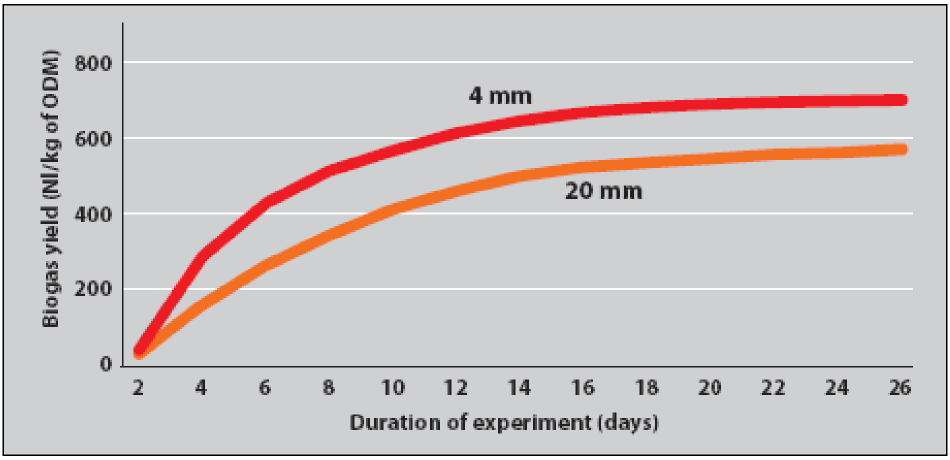

Fig. 2. Effect of chop length of maize silage on biogas yield (batch test, 26 days) [Schaumann,2006]

1.2. Maize chopping for needs of dairy cows

The Penn State Forage Particle Size Separator (Fig. 3) is available to quantitatively determine the forage particle size. The concept of forage particle size analysis and having a standard method for this forage particle size analysis begins with harvesting forages at the proper stage of maturity.


Fig. 3. Penn State Separator for determining the forage particle size [Jud Heinrichs, 2000]

Table 1. Recommended chopped maize particle sizes
for the Penn State Separator [Jud Heinrichs, 2000]

Corn (maize) silage	
Upper sieve[1] /particle size/ (>0.75”) (>19 mm)	2-4 % if not sole forage 10-15 % if chopped and rolled
Middle sieve[1] /particle size/ (0.75-0.31”) (19 mm - 8mm)	40-50 %
Bottom pan[1] /particle size/ (<0.31”) (<8mm)	40-50%
[1] Forage sample remaining on the screen	

Harvesting silage maize for needs of dairy cows (Table 1.) means that about 40 to 50 percent of the silage material measured is in both the middle sieve (particle size is between 8 – 19 mm) and bottom (particle size is under 8 mm) pan of the separator.

Adequate forage particle length (Table 1.) is necessary for proper rumen function. The finely chopped forage can exhibit the following metabolic disorders: reduced milk fat percentage, displaced abomasums, an increase in the incidence of rumen parakerotosis, laminitis, acidosis, and fat cow syndrome (Jud Heinrichs, 2000).

2. Method and material

During measuring examination of forage harvesters length of chopping time and distance coved at examination by harvester were measured by HI-204E GPS unit.

Mass of chopped biomass was collected in trailer and measured by weighing bridge.

For measuring of diesel engine fuel consumption PLU 116 H, and FLOWTRONIC 210 instruments were used. Measured data were collected by Spider 8 portable instrument and processed by IBM X600 portable computer.
At harvesting silage maize measurements were made in 3 times repetition at 4,0; 5,5; 7,0 9,0,14,0 and 17,0 mm theoretical chop lengths (Fig.5). Distance between cylinder pairs was 4 mm (Fesus et al, 1987, Jovan and Kelemen, 1990, Kelemen, 2004, Kelemen, 2001, Kelemen and Kocsis, 2008).

From measured data we counted the working speed, the throughput, the specific fuel consumption of forage harvesters. Sample was retained in 2 times repetition from chopped silage maize at every theoretical chop lengths. In the samples of chopped silage maize, the forage particle size analysis was made by Penn State Separator (Fig. 3).

3. Results and conclusions

John Deere 7400 | Krone Big X | New Holland FX58

Fig. 4. Forage harvesters involved in MGI's new measuring examination (Kelemen, 2004, Kelemen, 2001, Kelemen and Kocsis, 2008)

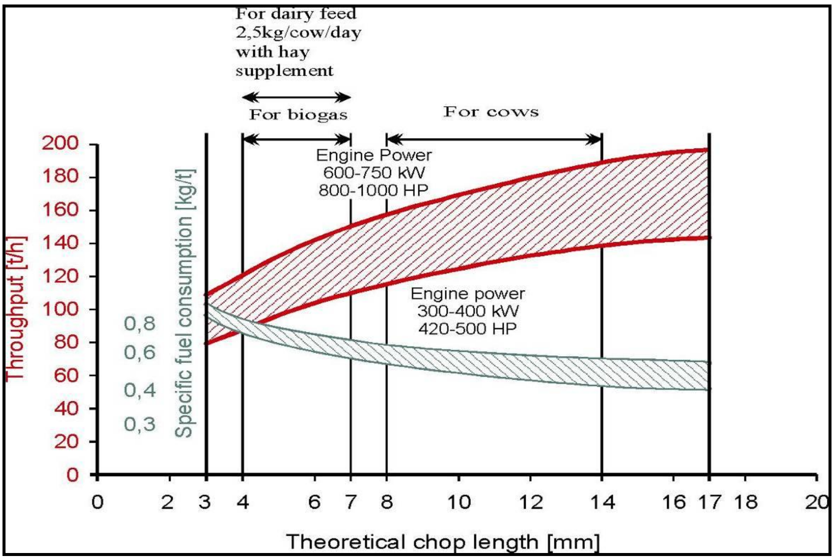

Fig. 5. Throughput and specific fuel consumption of self propelled forage harvestes with large capacity depending on maize chop length (Kelemen, 2004, Kelemen, 2001)

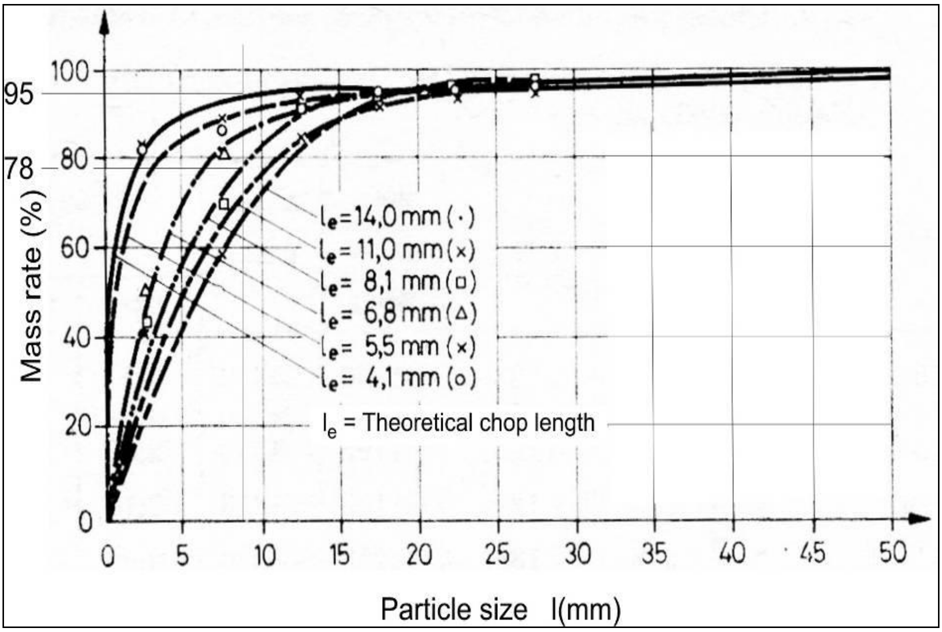

Fig. 6. Result of harvested maize particle size analysis at theoretical chop length (Kelemen,2004, Kelemen,2001)

Energy production connecting to dairy farms happens in biogas-plants utilizing livestock manure originated from animal plants. It is spreading in our national practice that biogas-plants are also built in the neighbor of dairy farms (and piggeries and poultry plants) to utilize their manure. For the increasing of biogas output and profitability of biogas-plant they put higher energy contained crop (energy crop) to the livestock manure in the fermentor of biogas-plant (Bense et al., 2007, Kauter and Claupein,2004 , Moeller, 2003, Szendro et al., 1998).

The dairy farms generally produce crops as energy crops that they have had practice in producing and harvesting process and that they have had background machinery.

Our animal plants for purpose of biogas-plant generally cultivate the following energy crops: maize (some kind of grasses, Sudanese grass, sweet sorghum). In a dairy with 200 milked cows for purpose of biogas-plant being built for example they cultivated 100 hectares maize as energy crop. The yearly production of maize was about 4.000 tons, which is canned as maize silage (Walland, 2001).
When we want to harvest silage maize for needs of dairy cows the chopping length is between 10-20 mm theoretically, and 4 and 7 mm for needs of biogas facilities (Fig. 5 and 6). According to measurements of our institute (Hungarian

Institute of Agricultural Engineering, MGI) the throughput of self propelled harvesters (Claas, John Deere, New Holland) (Fig.4), for needs of dairy cows is 150-200 t/h, and 70-100 t/h for needs of biogas facilities (Kelemen,2004, Kelemen,2001).

The forage harvesting capacity of a self propelled harvester is about 7.000-10.000 t/year for biogas facilities and 10.000-20.000 t/year for dairy cows in harvesting silage maize.

The expected maize silage yield is between 20-40 t/ha, and the harvestable maize silage production area with a self propelled harvester is about 120-500 ha/year for biogas facilities and 240-1.000 ha/year for dairy cows.

In these days the forage harvester manufacturers recognize the different chopping length demands and they intend to satisfy any users. They produce self propelled harvesters with 300-700 kW engines because of the higher chopping demands. For the balance of chopping performance they use more and more 12, 24 or 48 pieces "chopping knives" (Kelemen, 2004, Kelemen, 2001 , Kelemen and Kocsis, 2008).

At self propelled harvesters the user can change the size of the chops by remote controller with the hydraulic carrier as well.

Acknowledgements

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INVESTIGATION OF THE DEPENDENCE OF DYNAMICS OF BIOGAS PRODUCTION AT MAIZE SILAGE AS AN ADDITIVE RAW MATERIAL

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Abstract

Maize silage is a practically used adding material for biogas production. Three trials of different length range of silage were investigated in laboratory for measuring gas production. The basic material was cattle slurry wherein the three samples were mixed. As a result we found that for measuring the effect of size and content of silage used for biogas production is difficult but it has an effect on biogas productivity and dynamics. We also found that the new biogas measuring system has been being developed needs to be improving at gas volume measurements and mixing.

Keywords

maize silage, biogas, biogas measurement, cattle slurry, Synergy2009.

1. Introduction

Co-fermentation is a practical way to increase biogas yield. Added materials can be especially cultivated plants as different cereals, maize, etc. For improving the economy of biogas plants and for increasing the capacity of biogas production, codigestion of energy crops has become popular in agriculture. Seed breeding companies have started to design high-yield energy crops, and farmers have tested new methods for achieving two harvestings of energy crops per year (Weiland, 2003). According to ATB lab scale experiments most remarkable are the biogas yields for barley and rye at milk stage. Beside this there were no great differences found in the methane production from fresh matter or from silage. (Heiermann and Plöchl, 2004). Although ensiling is the method of choice for the preservation of energy crops plant operators often show little awareness that this process affects both energy losses during storage and specific methane yields. The presumption that ensiling generally improves methane yields is not supported by the results, still it seems that longer storage has a favorable effect on the digestibility of the silage (Neureiter et al., 2005). Maize should be conserved as silage prior to anaerobic digestion as this increases the methane yield. Late ripening varieties (FAO ca. 600) make better use of their potential to produce biomass than medium or early ripening varieties. Maize is optimally harvested, when the product from specific methane yield and VS yield per hectare reaches a maximum. With early to medium varieties, the optimum harvesting time is at the "end of wax ripeness". Late ripening varieties may be harvested later, towards "full ripeness". Farmers are advised to harvest maize when the dry matter yield per hectare reaches its maximum and maize can still be silaged. Maximum methane yield is achieved from digestion of whole maize crops. Digesting corn cob mix, corns only or maize without corn and cob gives 43-70% less methane yield per hectare (Amon et al., 2007). One of the most important factors influencing corn silage quality is moisture content at time of harvest. Harvest considerations should also focus on obtaining the correct particle size distribution and the need to process the crop. The recommended density of > 230 kg of dry substance per m3 of silage can be reached by adhering to the optimum shredder chip length for silage maize of 5 to 8 mm. Material that meets these requirements can be easily processed, causes minimum energy loss and thus offers high gas yields (Schaumann Bio Energy). There are different sizes of chopped parts in normal feed maize silage from 0.5 cm up to 10 cm. Three trials of different length range of silage were investigated in laboratory for measuring gas production. These measurements were done at the Hungarian Institute of Agricultural Engineering in Gödöllő (MGI). MGI have had a biogas laboratory with 20 reactors at sizes of 1 litre, but for this investigation a new system with bigger size reactors was needed. A new biogas laboratory has been developed as a second level of gas production measurement. During the research in the new laboratory a new biogas measuring system with new equipment was also tested and analysed.

2. Materials and methods

A new batch reactor system was built up for the measurement as a second laboratory scale. The reactors about 10 litre sizes were stored in a water thermal bath and were keep in a thermopile temperature zone. Each reactor has a mixing movement and also a connecting rider for pH sensor. The basic material was cattle slurry as an inoculum wherein the three samples were mixed. Produced gases were measured in a closed system with weight equated glass gas containers of 1000 ml. Besides this the time of measurement period, temperature, the pH value and the dry matter of the slurry were determined. The samples were maize silage originated from a bunker silo from an existing dairy farm so it was prepared in a normal practical way. The whole crop maize was chopped and ensiling. The three samples have been made by separation of different size parts of trial silage into 2 fractions. First one contained small parts that were less then 2 centimetres. Second one has the longer parts and a third sample has a 50-50 % mixture of them. Each trial about 6 litres respectively has 3 repetition. Trials were mixed periodically and the measuring period were 20 days.

Fig. 1. Preparation of samples

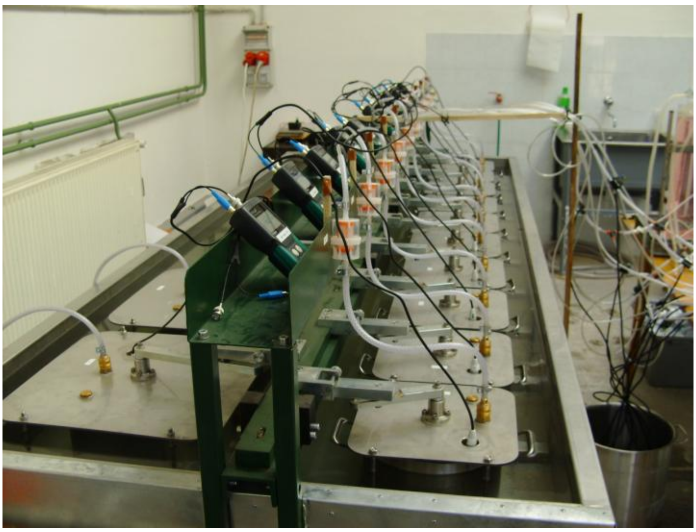

Fig. 2. Measuring system

There were no deep analytical examinations of trials, only dry matter contents were determined and pH values were continuously registered. Gas concentrations of produced biogas were also not measured at this first test measurement. During the measurement we tested the new biogas measurement system, so we focused our attention on correct working and gas leakage.

3. Results and discussion

Using raw dairy cattle slurry as a basic material without inoculum takes our measurement indefinite, so results can be analysed after the stabilized status. Data presented in Figure 3 show specific biogas production from the 13th day of the investigation till the end. It was seen that the biological activity on the digesters starts to increase and the control starts to decrease from this time. Most remarkable results are:

- The gas production of small fraction is bigger than long part fraction.
- Whole Maize plant is better, then Sorghum as gas-purpose biomass.

There was no significant difference among the DM content of trials (11,8 – 12.4 %) so effect couldn't be shown. During the measuring period pH values have decreased from 6,55-6,9 to 5,1-6,02. Remarkable coherence could not be shown between pH value and biogas production changes.

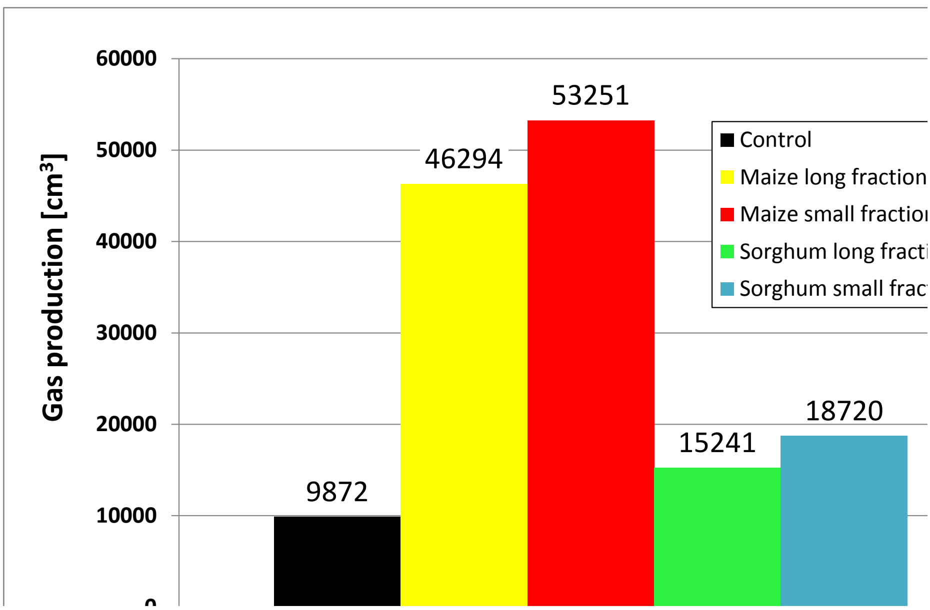

Fig. 3. Specific gas production

The measurement system needs to develop by a new mixing technique, because the co-fermentation material could not be homogenized properly. After gas leakage fixing all other components worked well, only new mixing equipment should be worked out. It is desirable, that an instrument for gas production measurement should be used that is able for continuous measurement.

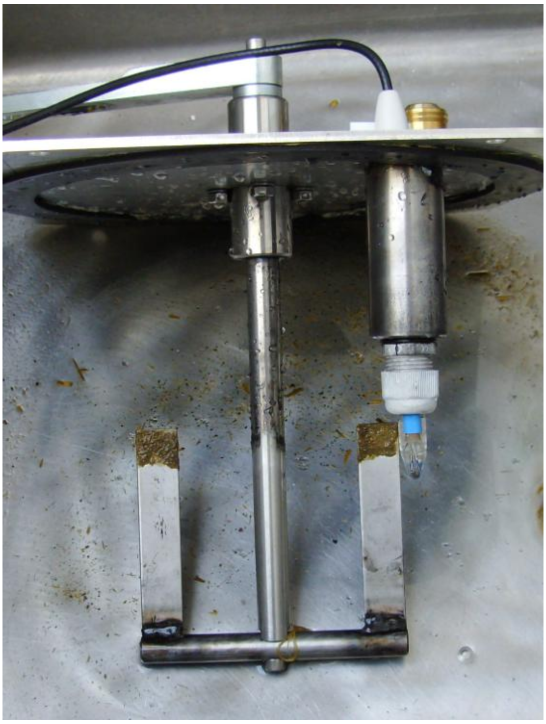

Fig. 4. Tested mixing paddle for homogenization

4. Conclusions

As a result we found that the new measurement system needs to be improving at gas volume measurements and mixing. We also found that for measuring the effect of size and content of silage used for biogas production is difficult but it has an effect on biogas productivity and dynamics. Main reason of initial surprising result is the high fodder content of slurry. Further possible reason that the structural samples behaves as absorbent, and in first step in the reactor fixed coated biogas production takes place.

Acknoledgement

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IMAGING METHOD FOR LENGTH ESTIMATION OF THE WILLOW SLICE

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Abstract

In the field of agriculture and in many other cases digital image processing is a popular and important instrument. An important area of application of image processing is the quality assessment of food and energy plants by visual appearance . In the field of agriculture different chopped materials from energy plants can be used as an alternative energy source. During the utilization the chopped material length is an important parameter. In this respect willow is one of the potential raw material. This article provides an imaging method which has been specifically designed for the investigation of chopped willow. The article comprises both the hardware and the software solutions, and describes the experiences, environments and applied materials.

Keywords

Image processing, chopped willow

1. Introduction

Agricultural byproducts / plant choppings are used in many distinctive areas of industry and agriculture. Plant choppings can serve as livestock forage, litter, organic manure and energy resource. In all cases the measures and size distribution of choppings is an important parameter (Szendrő, 1995, 1998). Presently size of choppings is measured manually. Digital image processing is a possibility to provide a partially or fully automated method for measurement (BOCKISH, 1989).

1.1 Objectives

Primary task of the research is to undertake analyses on given pieces of the woodchips in order to define the respective geometrical characteristics (Szabó et al., 1996).

Based on sample pictures tests have to be undertaken to identify the best image processing method(s) for the implementation of the shape recognition nessary.

During the assessment of the respective characteristics, the relationship between physical and geometric parameters has to be examined. In the experiments it is deemed necessary to examine several sizes as the chopping machines deliver a wider variety of thread length (in the interval of 0.5 cm to 15 cms). We have to also take into consideration the wide range of crosscut parameters, and can even vary inside the same plant.

Based on additional experiments a further goal is to find a qualitative descriptor which can be utilised later in the technological processing of spalled sallow (Granitto et al., 2002).

The enumeration of geometrical parameters (of chopped plant partitions) is not a necessary or sufficient condition of describing the qualities of a set of plants.
It can be therefore stated that it is necessary to identify information relevant to the set which can be referred to predefined physical parametric values.

1.2 Material and method

For the purposes of the analyses described in this paper choppings of energy sallow were used cut intentionally to different lengths. Images were taken with the following three optical devices (cameras):

- USB webcam with 2Mpixel resolution (QuickCam Pro9000)
- 15 Mpixel resolution camera remotely controllable from USB (CANON EOS500D)
- Industrial camera with Ethernet connection (scA1390-17gm, 1392x1040, 17 FPS)

Cameras were interconnected to IBM PC compatible computers.

The system functions are as follows:

- W_1, W_2 image input with analogous or digital relaying/transmission.
- W_3 processing and conversion with external control option.
- W_4 interconnection,switch.
- W_5, data storage and inteconnection with external control option.
- W_6 router,. traffic control

Information to be processed is indicated with „**x**” while „**y**” represents partially processed information.

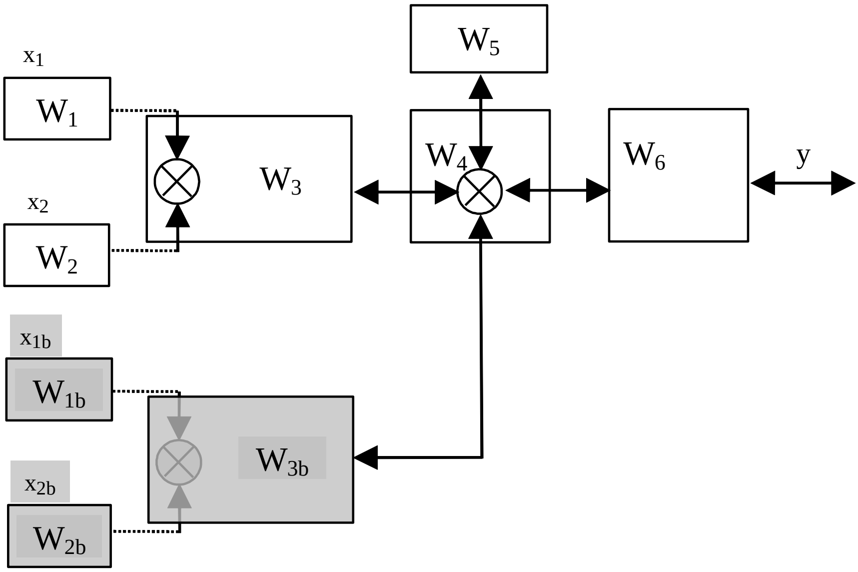

Fig. 1. Structure of the applied imaging system

The direction of the connecting arrows indicates possible direction of dataflow.. The system can be extended with optional functions (W_{1b}, W_{2b}……).

The operation of the system is done on MS Windows XP, image processing methods were developed in MATLAB, and C.

2. Results of experiments

2.1 Segmentation and measuring

Experiments undertaken with individual pieces of sallow choppings led to the development of a method which permits segmentation of iamge objects with high efficiency. The procedure starts with the color intensity cutoff of images in the background color spectrum. This is followed by the B&W conversion based on the intensity characteristics, then the edges of choppings are defined by a Sobel-operator.

Fig. 2. The original image and the segmented objects

The respective objects can be processed further after segmentation and edge detection [4]. Individual elements of sallow choppings were succesfully measured geometrically in the experiments.Measuring helps the size classification of choppings. However, during the 2D measurements, the measuring methods focusing purely on acquiring longitudinal sizes do not take into consideration the case when a chopping has a larger diameter than longitude (cutting length). This will result in the chopping aligned to the face (of the blade). Thus, the 2D measurements necessarily contain the data of choppings which are not aligned by their longitudinal axis. In these cases the surface of section is bigger than the surface of a perpendicular section therefore they can be falsely mapped to a different size class. In order to avoid this fallacy, a procedure was elaborated. The aim of this procedure was to determine if the object is circular. This was attained by comparing the circumference and area of the segmented object. If the quotient is near to 1, then, with high probability, we have a circular object.

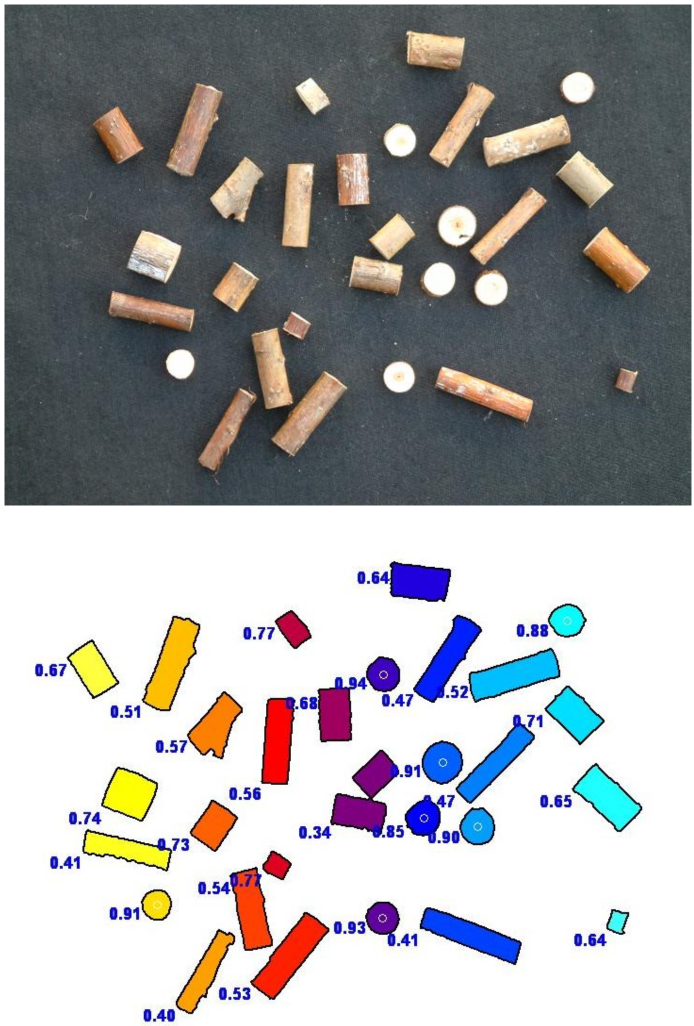

Fig. 3. The object is circular if the quotient of the area and circumference is close to 1

2.2. Results

The application of the described methodology brought the following results on a 100-element sample containing small size choppings only.

Those choppings, where the diameter was more than 30% larger than the section length were with high probability aligned longitudinally to the face. The proportion of these choppings in the sample were over 70% (!).

Examining the stalk-wise (normally) and longitudinally aligned element sizes we can draw the following chart:

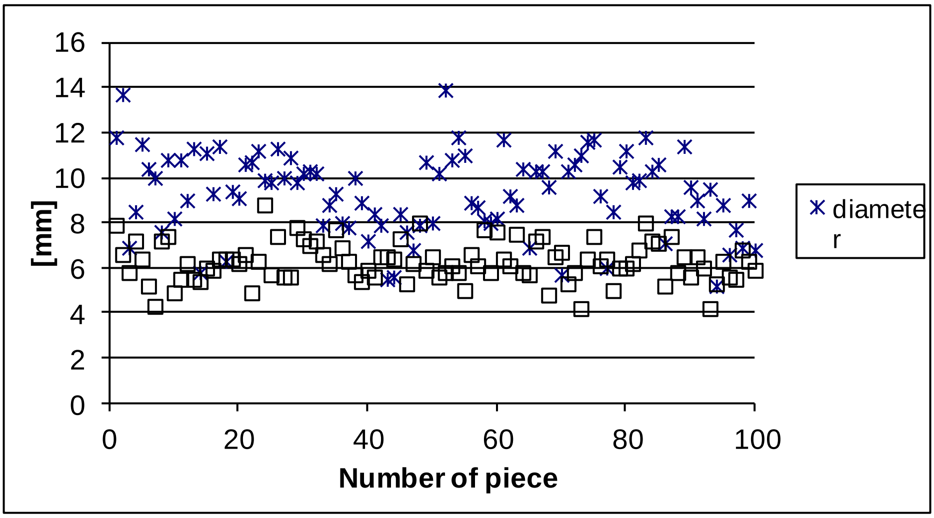

Fig. 4. The length and diameter values

It is well visible, that the set of measured diameters has a much larger variance, and the expected values for the two cases also differ significantly.

Typical values are shown in the following table:

	Min [mm]	Max. [mm]	Dispersion [mm]	Average[mm]
Diameter	5,2	13,9	1,78	9,3
Length	4,2	8,8	0,87	6,3

Considering the proportions to the larger choppings the nominal differences are not significant.

This size definition difference does not cause significant alteration neither in combustion nor in other technological utilisation.

If a dedicated equipment's chopping characteristics has to be assessed with imaging methods, then the fact that the smaller parts section variance is actually just half of the diametrical sizes can be considered a significant deviation.

Considering the above, if in the samples we replaced the circular objects' sizes with the 60% of the respective measured diameters during the experiments we gained the following values:

	Min [mm]	Max. [mm]	Dispersion [mm]	Average [mm]
Calculated length	4,2	8,3	0,81	6,1

3. Conclusions

Summarising the findings, it can be stated that the proposed measurement procedure applied in the experiments can be successfully used for the size definition and classification of the sallow choppings. For circular stalks and for section lengths smaller than the respective diameters the applied method gave a more precise average estimation than the conventional imaging algorithms which examine only the size and not the shape of the projection.

This, coupled with the prescribed precision for small fraction measurement can provide a useful contribution for machine configuration and machine classification.

Acknowledgements

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Hyperspectral Imaging and Reflectance Spectroscopy as Prospective Key Factors in Modern Site Specific Agricultural Production

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Abstract

Spectroscopy studies the interaction between electromagnetic radiation and matter. The method of evaluating the spectral characteristics of different biotic or abiotic materials and surfaces originates in the laboratory spectroscopy, where it was used in physical and analytical chemistry hence atoms and molecules have unique spectra. Today the technological development has made possible to carry out high spectral resolution in-field analysis and airborne hyperspectral imaging. This technology also creates new perspective for information management in site specific agricultural production. In this study we are introducing the technological basis of reflectance spectroscopy and hyperspectral imaging with some experimental results in modern agriculture.

Keywords

winter wheat, spectroscopy, hyperspectral remote sensing

1. Introduction

Remote sensing of Earth's surface includes several non-contact measurement techniques and evaluation methods. The dynamic development of the different remote sensing technologies resulted in the hyperspectral imaging spectroscopy, which is one of the most advanced technologies in optical remote sensing. It has greatly improved the efficiency of data utilization and created new perspective for modern information management in precision agricultural production.

The only physical connection between the observer and the object is the electromagnetic radiation. With the use of the hyperspectral remote sensing one can record the refletced radiation form the studied surface on hundreds of narrow, adjacent bands. Simoultaneously, gray-scale pictures are taken of these bands and recorded separately. This data recording method results in the so called data cube. In this high resolution of spectral information is assigned to all spatial pixel of the data cube, hence the spectral caracteristics of the surface can be mapped by high definition geometrical sampling method up to hundreds of adjacent spectral bands (Fig. 1).

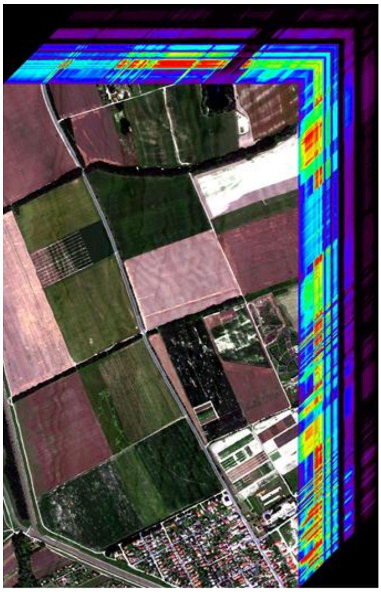

Fig. 1: Hyperspectral data cube

The integration of in-field and laboratory spectroradiometric measurements is adequate to analyze large areas in a fast, precise and economic way (Milics et al. 2010, 2011). Data acquisition in the field and under laboratory conditions the spectral sampling results in one pixel, which contains the mean reflectance of the instantaneously scanned surface (Virág and Szőke 2011).

In this study we introduce two systems which extend the range of the detectable visible light (Lágymányosi and Szabó 2009, 2011) to NIR (near infrared) and the SWIR (shortwave infrared) that are able to operate in the full optical wavelength range of 400 to 2450 nm (AISA DUAL) and 350 to 2500 nm (ASD Fieldspec®3 MAX). Furthermore we are introducing the preliminary results of identifying the spectral features, sensitive wavelengths or wavelength ranges which are characteristic to the changes resulted by different amount of applied nitrogen fertilizers with modeling different nutrition levels of winter wheat during field experiments. Yield, protein and wet gluten content of the studied winter wheat variety ‘Alföld 90’ was evaluated with conventional laboratory technology.

The coordinates of in-field experiments are recorded and the soil surface spectrum can be fitted to the adequate pixel of the hyperspectral airborne image that is an important element of the subsequent evaluation processes. The number and the quality of in-field measurements determine the final accuracy of the airborne images. Using this new generation data monitoring and sampling methods we can obtain quantitative relationships between the environmental and physiological parameters of the vegetation (Balla et al. 2011), soil quality parameters (Máthé et al. 2010, Tolner 2011) and different sources of soil contaminations (Csorba and Jordán 2010), climate attributes (Erdélyi et al. 2009, Tarnawa et al. 2011) and the features of reflectance spectra. The Department of Water and Environmental Management of the University of Debrecen, Centre for Agricultural and Applied Economic Sciences (Kőmíves et al. 2006) and the Hungarian Institute of Agricultural Engineering (later Institute) operate the AISA DUAL sensor system of the Finnish Specim Spectral Imaging Ltd. In the year of 2010 the Institute bought an ASD Fieldspec®3 MAX field spectroradiometer to develop the available data acquisition system. The Hyperspectral Working Group of the Institute offers new generation of data acquisition methods. Beyond the scientific application of the technology services there are available adequate hyperspectral methodologies to meet the agricultural, industrial and other scientific needs.

2. Materials and Methods

The AISA DUAL airborne twin-sensor (Fig. 2.), which consist of the EAGLE (Fig. 3.) and HAWK (Fig 4.) sensors, that has the potential for detecting the electromagnetic radiation in the wavelength range of 400 to 2450 nm with sub-meter level of spatial precision. During the flight the geographical coordinates and the position of the plane are recorded by Oxford RT-3000 GPS/INS system. Beside the DUAL mode both sensor can be operated depending on the aim of the experiment

Fig. 2. AISA DUAL

Fig. 3: Hawk

Fig. 4: Hawk

For laboratory tests we constructed a light-isolated cabinet where disturbing environmental light is shielded. The ASD Field Spec®3 MAX portable spectroradiometer and the laboratory cabinet are presented in FIGURE 5 and FIGURE 6. The undesirable reflection from the interior of the measuring cabinet is minimized by the appropriate arrangement. The special material of the cabinet's interior results in minimal reflectance over the whole electromagnetic spectrum detected by the spectroradiometer (350-2500 nm).

Fig. 5: ASD Field Spec®3 MAX

Fig. 6: Laboratory cabinet

On of the disturbing factors during the spectral measurements is illustrated by the following figure (Fig. 7.) During this experiment the doors of the cabinet were not closed properly (in order to show the effect of the light infiltration). This way the assumption of the isolated experimental space was damaged. Due to the light infiltration two reflectance peaks appered at 520 nm and 640 nm. These false signals can easily supress, or modify those spectral caracteristics that one is seeking for during the data process.

Fig. 7. Spectral disturbance caused by unfavored light infiltration

Experiments were carried out to identify the spectral differences of winter wheat treated with various nutrient dozes. ‘Alföld 90’ winter wheat variety was tested on agronomic replicated blocks with 7 replications (Fig. 8.)

Fig. 8. Experimental field (phenofase of tillering – left and shooting – right)

Each replication had two variants: fertilized (4 plots) and unfertilized (4 plots). The experimental plot size was 10 m^2. All fertilized variant (28 plots) received 80 kg ha^{-1} nitrogen fertilizer in form of ammonium nitrate (0-0-36), unfertilized variants (28 plots) did not receive any mineral fertilizer. The difference generated by the impact of various nutrition levels were tested with the yield (kg/plot), plant height (cm), ear size (cm), and quality parameters as protein (%), wet gluten content (%).

Wheat ears were collected from all plots and analyzed in laboratory according to its spectral characteristic with the spectroradiometer in the wavelength band of 350 to 2500 nm. The samples were illuminated and tested with the use of ProLamp. The kernel samples were tested by the use of PlantProbe sensor-head (Fig. 9.)

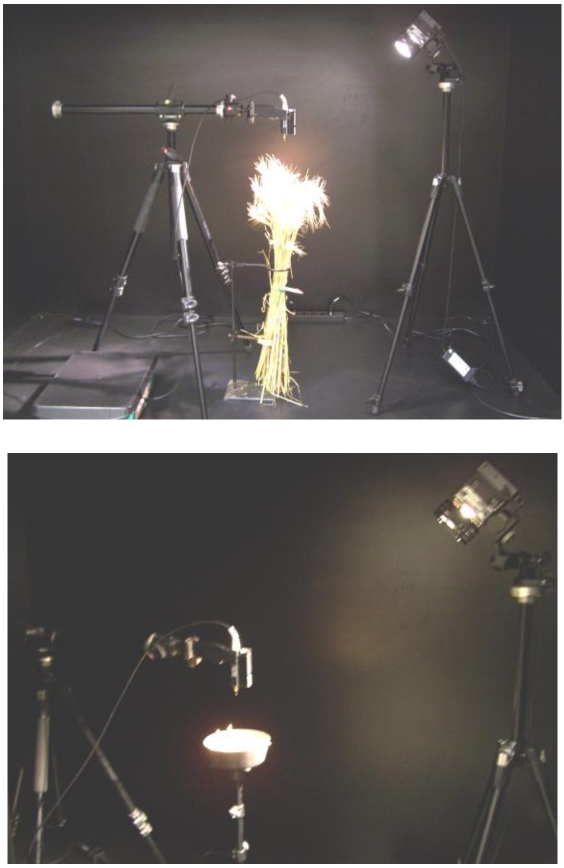

Fig. 9. Measurements carried out by using ProLamp for illumination

The pre-processing of the spectral data was made with ViewSpecPro software. Further processing steps were carried out with ENVI image analyzer software. We used continuum removal technique to normalize reflectance spectra. This made possible to compare the absorption features according to the common baseline (ITTVIS ENVI Image Analyzer).

3. Results and Discussion

The ratio of ear size to plant height showed that nitrogen fertilizer reduced this ratio relative to the untreated crops. Nitrogen also resulted in higher yield. The analysis of the protein (Fig. 10.) and the wet gluten content (Fig. 11.) approved the correlation with the amount of ammonium-nitrate fertilizer. As a result of the treatment all values decreased significantly.

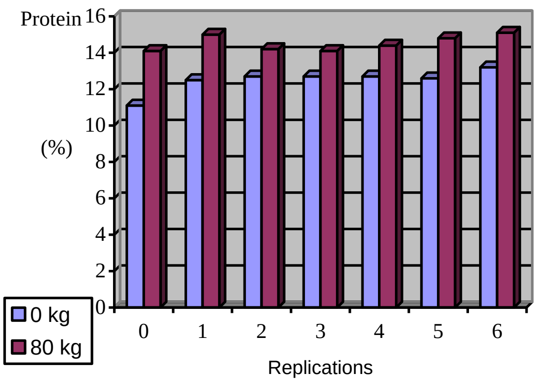

Fig. 10. Protein

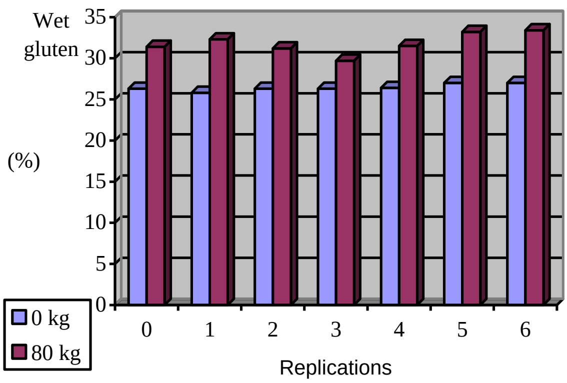

Fig. 11. Wet gluten

The mean reflectance spectra of the treatments were computed when evaluating the wheat ears (Fig. 12.) and kernels (Fig 13.) by spectroradiometry. Red line represents the nitrogen fertilized, while green the non-fertilized crops. According to these curves the spectral characteristic of the different treatments are different, but the deviation seems to be independent on the differences generated by the use of mineral fertilizer.

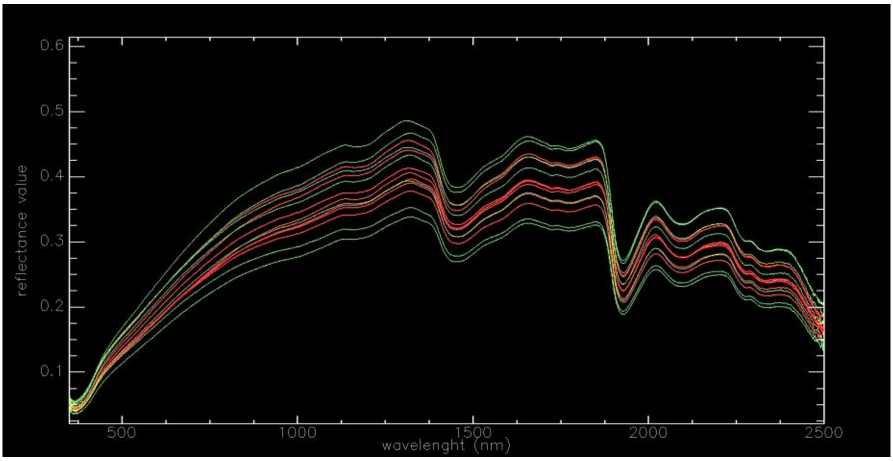

Fig. 12. Wheat ears

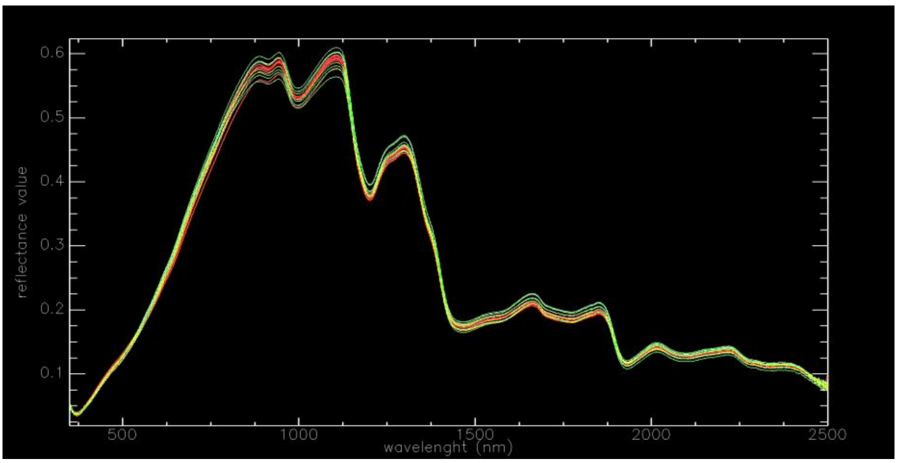

Fig. 13. Kernels

After normalizing the reflectance spectra a characteristic interval were found both at wheat ear (Fig. 14) and kernel samples (Fig. 15).

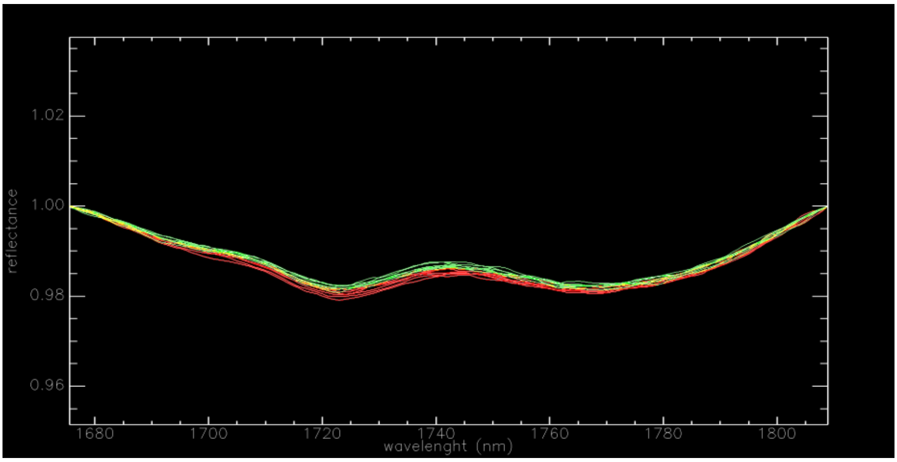

Fig. 14: Wheat ears (1650-1800 mn)

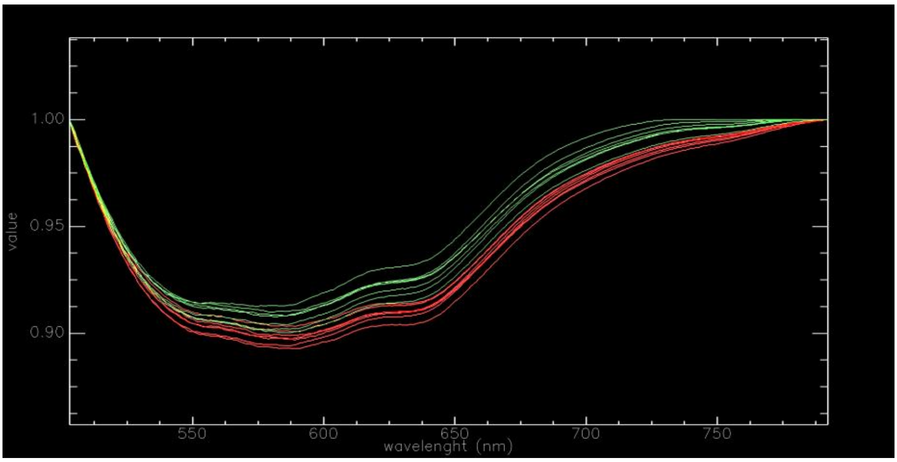

Fig. 15: Kernels (500-800 nm)

4. Conclusions

Different nitrogen fertilizer doses resulted in different quantity and quality parameters of the tested wheat variety. These differences also generated some changes in spectral features of wheat ears and kernels.The curves of the nitrogen treated and untreated samples show the same spectral change. A decreasing trend in values of signal ratio of the nitrogen treated samples can be assessed in the 1650-1800 nm and 500-800 nm wavelength ranges. After the appropriate calibration and validation process the spectral instruments can contribute to the better description and tracking of the current dynamics of nutrient supply and plant up-take in a fast and economic way.

5. Acknowledgements

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VEHICLE TIRE PROFILE INVESTIGATION WITH 3D IMAGING

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Abstract

Visual appearance is a key factor for many industrial products in terms of quality. The most important attributes are colours and shape. Digital image processing is a popular and important application to investigate visual appearance. Conventional 2D-imaging provides a good implementation of colour identification, but is not a perfect solution for surface monitoring [Koschan, 2008]. 3D laser imaging as a new technology provides some additional data on the investigated objects, beyond conventional imaging. Three dimensional representation looses colour information of the object, but provides a point to point surface mapping. This article aims to present the advantages of 3D-imaging over conventional imaging in terms of additional data by presenting results of an application of 3D-image analysis. It is concluded that the additional information gained can be used to describe object surface features in a more thorough manner.

Keywords

image processing, surface analysis

1. Introduction

It's important to know the status of the tire for the safety of the car. The abrasion, patterns of wear and tear, the deformation of the tires can provides information about the condition of the suspension There are also environmental benefits for such an analysis, as the too early change of tires generates an excess amount of waste. In 2015 1.72 billion tires are expected to be sold globally [Jose, 2010]. Otherwise, the condition of the tires influences the consumption of the vehicle.

2. The applied systems and materials

The applied apparatus

Throughout the experiments a 3D laser scanner of the type Zscanner 700 was used. The main technical parameters were: sampling rate 18000 sample / sec., 2 built in cameras, improved resolution of 0,1 mm, maximal accuracy of XY positioning is 50 µm if the investigated volume is 100 mm x 100 mm. The applied computer was a PC with the following features: I7 quad processor, 6Gb memory, graphical subsystem with 1Gb memory. The connection between the scanner and computer was an IEE1394 interface.

The investigated materials

The examined materials are car tires. The filtering method was as follows: 2 classes were applied, one where two of the tires were brand new, and one where two of the tires were heavily used.

The used programs

Geomagic - This program can repair the broken scanned surface.

MATLAB - This is a program and a programming language, too. MATLAB was used, because it has lots of useful built-in functions and additional functions can be added without problem if necessary.

The method of investigation developed

During the experiment lighting was applied with no extra requirements in mind. In the preparation of the scanned recordings exclusively a filtered artificial lighting was used to ensure minimal bias over the scanner's own lighting apparatus. We placed white paper points (reference points) to the examined area of the tire, as orientation points for the scanner. Multiple layers were necessary to provide an environment which is the closest possible to the surface exhibited by real material sets. Surface was always normalised to ensure that its unevenness only relates to size irregularities of respective elements. For most situations, a single scan will not produce a complete model of the subject. Multiple scans, even hundreds, from many different directions are usually required to obtain information about all sides of the subject. These scans have to be brought in a common reference system, a process that is usually called alignment or registration, and then merged to create a complete model. This whole process, going from the single range map to the whole model, is usually known as the 3D scanning pipeline [Bernardini, 2002].

Fig. 1. One class of investigated material

3. The investigations

During the analysis all classes were 3D-scanned.

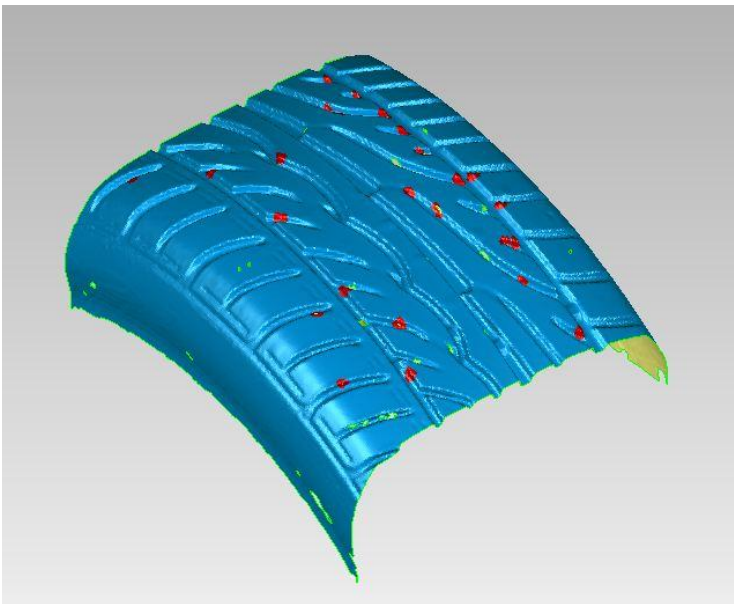

Fig. 2. One example of the scanned material

As we see, the originally scanned picture is full of holes. This is due to the inherent error of the scanning process. To repair these holes we used a program called Geomagic.

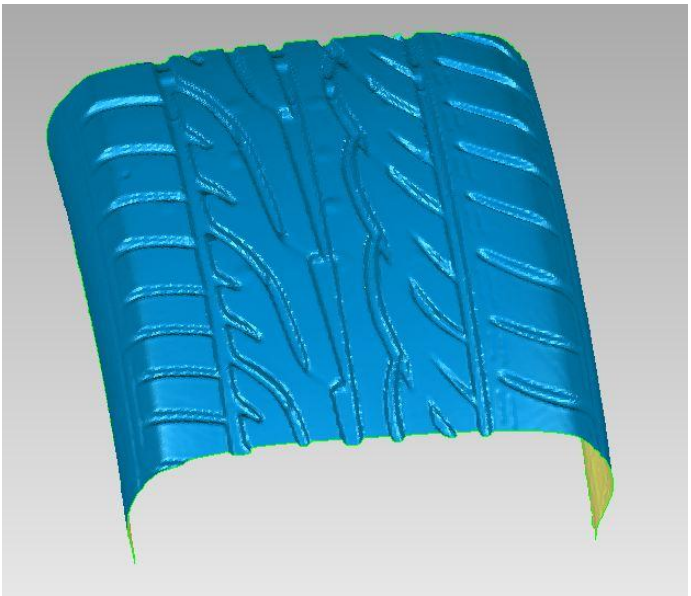

Fig. 3. Fixed surface

Scanned images represent the surface of the examined tire. The respective points of the image can be stored in a 3D matrix. The size of this 3D matrix would be too large for calculations, so we cut out the middle region of the surface and used this for calculations.

Examining a 2D slice matrix of the 3D matrix allows us to get a cross-section of the scanned material set. If the cross section is selected perpendicularly to the surface, we get a cross cut image of the original set. 'X' and 'Y' axes scale are in [mm]-scale and $x = 0$ is the geometrical center.

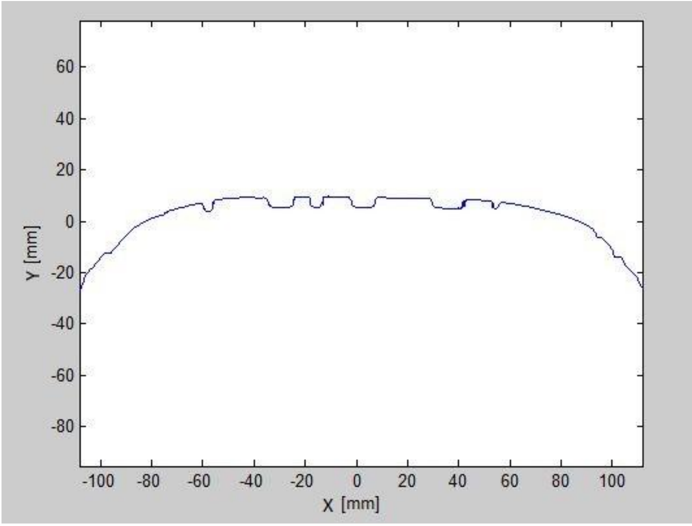

Fig. 4. 2D slice from the 3D matrix

After the ‘Z’ plain selection, an algorithm found the local maximum values from an interval. The interval size was 20 mm, because this is the upper limit for the largest groove in the surface.

The program was then used to fit a curve to the local maximum points. This curve is a fifth degree polynomial, it’s the simplest curve that gives a sufficiently good fit.

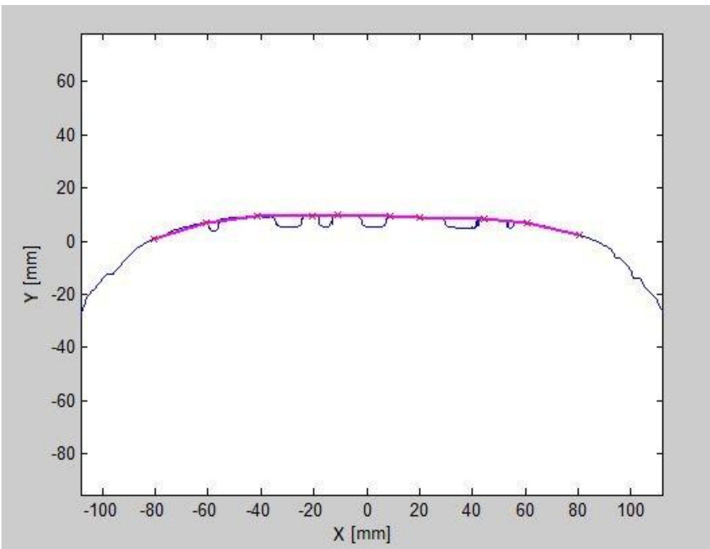

Fig. 5. Local maximum values with curve

The program was used afterwards to determine the location of the center of the profile, the half of the depth of the middle groove and moved the polynomial to that point. The points above the curve were useful, the points under the curve were useless. The useful points are where the tire connects with the ground.

Now we can calculate the length of the useful tread in the cross section and compare to the full tread. The length of the full tread is the length of the polynomial. The result of this comparison matches the expected results (70-75 %).

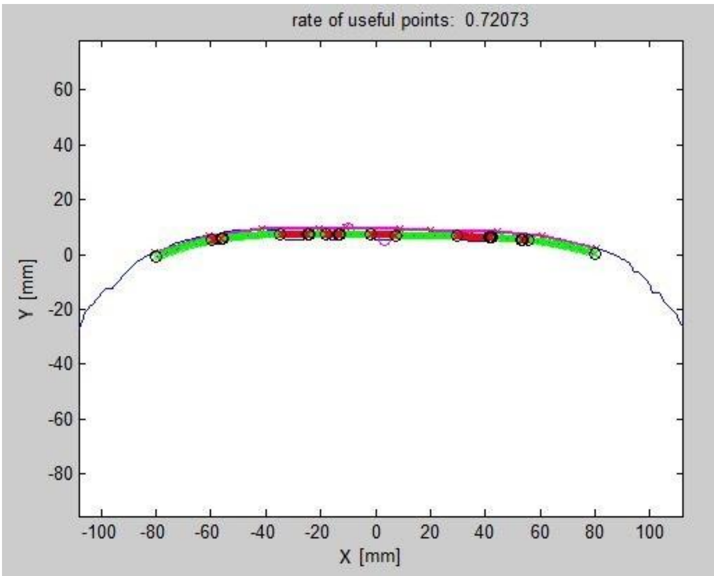

Fig. 6. Proportion of useful tread

Results and measured data
For the better perception we modified the scale from 1:1 to 8:1 in the 'Y' axes.

The above figures well demonstrate the effect of abrasion. The figures show the fitted polynomials for the respective tires. It is well demonstrated that Profile C shows the worst condition and Profile D is from a new tire.

This method allows for the construction of a mathematical model of the profile of a tire with the fitting of a polynomial. The formulated model can then be used to compare different types of tires and can represent the abrasion mathematically.

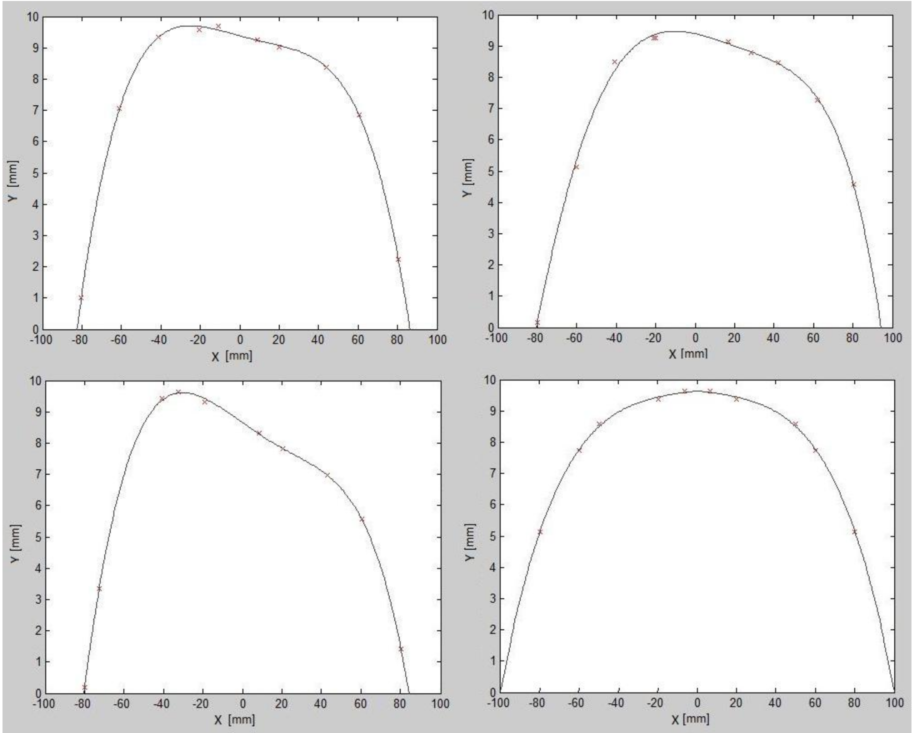

Fig. 7. Profile A, B, C, D

For example the polynomial of the profile on figure 5 is:

$$
\begin{aligned}
&-0.00000000004496x^5 - 0.00000019553168x^4 + 0.00000416301428x^3 + \\
&0.00006151861002x^2 - 0.01693044954352x + 9.38344604745602
\end{aligned}
\qquad \textbf{(1)}
$$

4. Conclusions

Summarising the results, we can conclude that the 3D-images of a tire can provide a valuable starting point to assess abrasion. With the developed mathematical model the abrasion of the tire can be examined in detail and can be used to indicate abnormal abrasion. The ongoing research is expected to provide applicability in a broader size spectrum by further refining and modifying the applied methodology. Additional objective is the crosscut image generation without 3D imaging as this would result in a real-time industrial applicability by making evaluation faster and simpler.

Acknowledgements

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APPLICATION OF 3D SCANNING IN ENGINEERING DESIGN AND ANALYSIS

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Abstract

In our research work we tested the conventional methods made moldboards. Below the testing processes are presented, covering practical and mathematical applications. The used tools and the examined mouldboard will be presented. This article summarizes the objective and empirical results that can be gleaned from the results and conclusions.

Keywords

agricultural, 3D scanning, mouldboards, surface analysis, crop

1. Introduction

The mechanization of the agriculture was already significant from the end of the 19th century and this sector's technical development accelerated rapidly. Our topic's subject is the mouldboard which is an important component of the soil tillage plow. The mouldboard has got a special free surface. For editing these surfaces we have to use specified methods.

Modeling the surfaces or their numerical description is not as simple as the determination of an elementary geometry such as a description of a flat or a cylinder surface. However the editing of these multi curved surfaces can be divided into elementary geometrical sections. Before the appearance of the computer science, planning the mouldboard was based on handmade edits, then after finished the testing of the prototypes it was able to develop through experience.

Nowadays with the high capacity computational background is not only possible to product a computing geometry, but testing the geometry of the mouldboard effect for the soil flow. The first picture represents the effect of the mouldboard's geometry to the plow's efficiency. All these requires to testing the geometry of the mouldboards. We made morphological tests in our own edits and geometric models, furthermore with digitizing the existing mouldboard we recognized the function of the definig parameters of the plow. Of imaging methods, the 3D laser scanning imaging method is used in the recent decades at testing the free surfaces after production. For the investigations we studied the preparation of the existing techniques than selected the most suitable system of tools and methods.

So the actuality of the topic is the research of the "old" conventional device with a "modern" geometric modeling tool.

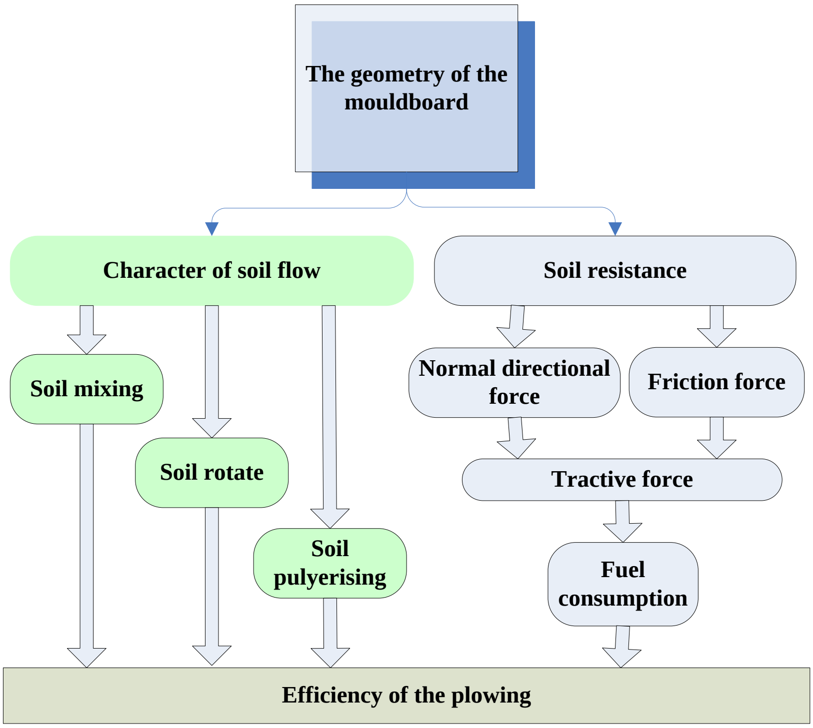

Fig. 1. Effect of the mouldboard's geometry to the plow's efficiency

2. Methods and Materials

In our study we performed several practical measurements and scanning by different types of mouldboards, to lean on theoretical knowledge. The second figure demonstrate sub-elements of the research process in high scale.

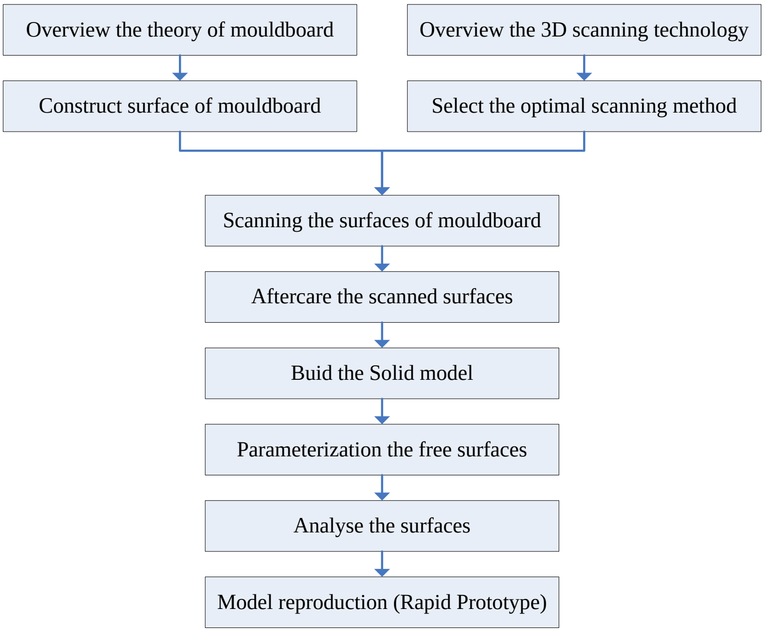

Fig. 2. Sub-processes of investigation

Applied devices

To carry out the computerized testing was required to use a complex toolbox. In the process of digitalization we converted the analog signals to digital signals. In our researches we used several attributes, according to the current model. Besides the software's project files (*. stl) file extensions were used during the scanning and post productions. In the parametric editing system the CAD system's own (*. sldprt) extension was applied. For the math tests, determine the n-degree polynomials (*. obj) extension was used.

Fig. 3. ZScan 700 and ZPrinter 350

We used ZScanner 700 for the three-dimensional scanning of mouldboards, this can see upper. The laser scanner is a device which have two cameras, a laser unit and with an auxiliary light. This scanner can map digital surfaces with reference point. The device's accuracy is 50μm normal to the laser line and 100 μm parallel to laser. The scanner's available highest resolution is 0,2 mm.

As closing the research work, we prepared a real scale-model with a rapid prototyping manufacturing system. We used a ZPrinter 350 three-dimensional printer in this workflow, the third picture shows this device.

Materials of the research

In our research work we tested four different kinds of mouldboards as is seems in the 4th picture. We were chosen for the tests the culture and the half-twisted mouldboards which are used in the Hungarian agriculture. These mouldboards are made by Kühne. The samples were old and new as well so we could observe the abrasion characteristics. We were digitized all the sample's surfaces, but we only defined the culture mouldboard's control curve.

Fig. 4. The four different kinds of moudboard

The topic and the main goals of the research could be recorded if we know the necessary tools and methods. The final result of the research work is not just the determination of numerical results, but also a development of the method itself and an automatable process.

Based on these the desired goals can be fixed in the following three points.

- The numerical description of the mouldboard's surface.
- Compare an edited and a digitised mouldboard's parameters.
- To discover the limits and possibilities of the 3D scanning.

3. Research

Our investigations can be divided in three parts. To editing and scanning the mouldboard and the determination of the control curve. During the editing we have done the necessary calculations to the determinate the constructional sizes. We were made these starting from basic and empirical data. The geometric model's construction was made in CAD system. With the standard editing we wanted to set up a reference next to the digitized mouldboard. We would like to demonstrate the authenticity of modeling with this.

Mouldboard editing

In the standard editing should clearly define the type of soil and the type of machining. The first table includes these parameters. The width and depth of the plowing determinate the mouldboard's necessary sizes. Each angle range determinate the plow's character of tillage, the measurement of the rotate and pulverising.

Table 1. Basic parameter for mouldboard editing

The plowing depth	a= 270 mm
The width of the plow	b= 350 mm
Angel between the plow and the furrow	α= 30°
The angel of the main component	γ_0= 42°
The last component angel	γ_t= 47°

The following three equation (1. 2. 3.) illustrate the necessary contexts for the basic editing illustrated in figure number 5..

$$h = \sqrt{a^2 + b^2} = \sqrt{(270mm)^2 + (350mm)^2} = 442[mm] \qquad (1)$$

The "h" as a diagonal slice of the soil, determines the necessary height of the mouldboard.

To rotate a suitable piece of soil, an accurately created bending radius is needed. Therefore the minimal and maximal bending rays had to be determined with calculation. With the calculation on picture number 5 can be editing the mouldboard's projection of working surface.

$$R_{\min} = \frac{b}{\left(\frac{\pi}{2}-\alpha\right)\cdot\cos\gamma_0} = \frac{35mm}{\left(\frac{\pi}{2}-0{,}52\right)\cdot\cos 42°} = 459{,}7\ [mm] \tag{2}$$

$$R_{\max} = \frac{b\cdot\sqrt{k^2-1}}{k^2\cdot\left(\cos\alpha-\frac{\cos\gamma_0}{\sqrt{k^2-\sin^2\gamma_0}}\right)} = \frac{35mm\cdot\sqrt{1{,}4^2-1}}{1{,}4^2\cdot\left(\cos 0{,}52-\frac{\cos 42°}{\sqrt{1{,}4^2-\sin^2 42°}}\right)} = 667{,}7\ [mm] \tag{3}$$

In the editing can be seen the case of dimensional editing the mouldboard's surface can be performed by two surfaces. The closed surface specify the mouldboard's outer contour, the opened surface forms the working surface with the control curve and assistant components.

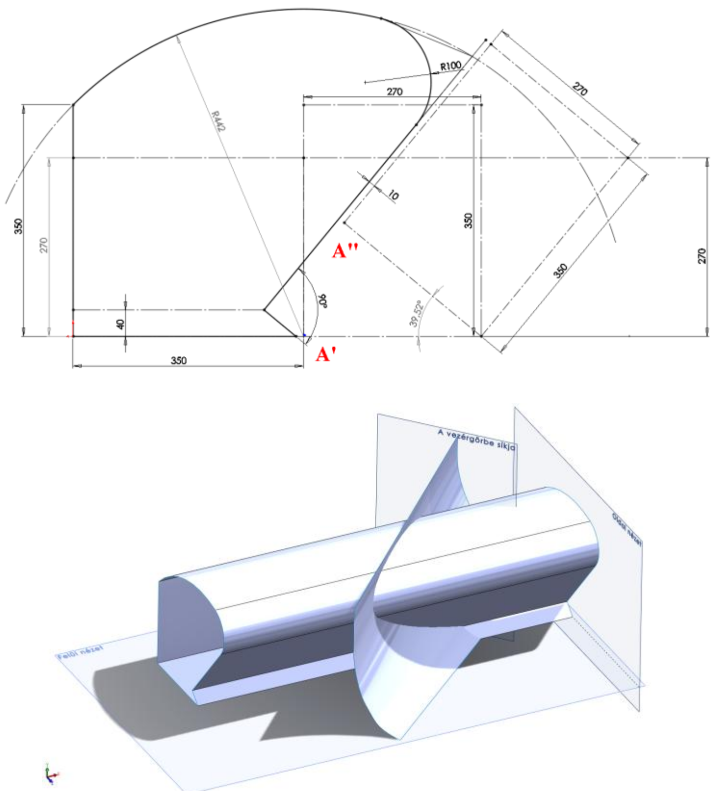

Fig. 5. The edited culture mouldboard

Mouldboard scanning

The chosen mouldboards are made with the previously described editing procedures. Without documentation, the free surfaces with this digitizing procedure can be reconstructed in a unique way. For the digitalization the model's surface had to be matte, and had to be added the necessary reference points.

The model prepared by the laser scanner is build up from a point cloud in the first step, which can be converted to surface or solid models with the model-building steps used by Reverse Engineering as W. Wang (2011) describes it.

In picture number 6 there are four different kinds of mouldboard's rough surface. These are suitable for the production of solid models after the appropriate post production.

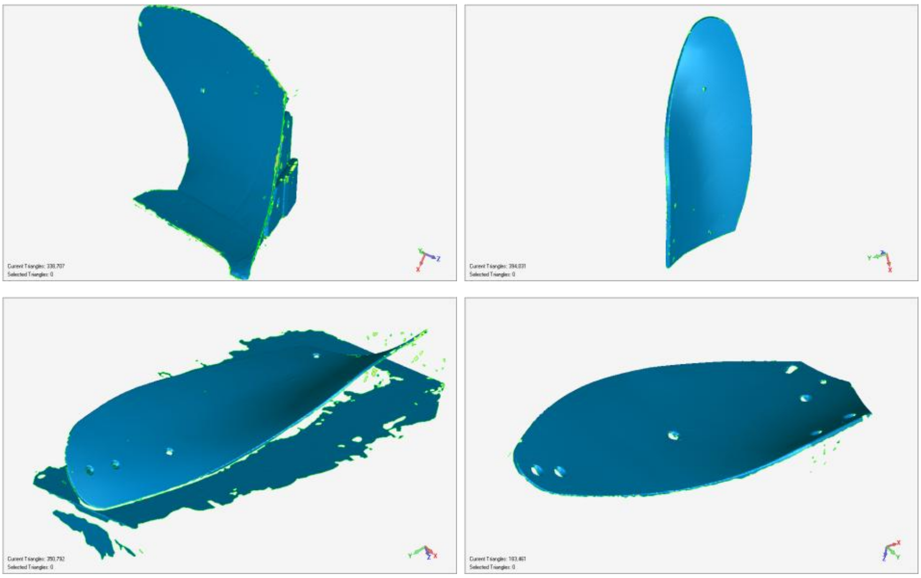

Fig. 6. The four different kinds of scanned surfaces

There are not discussed the practical steps of scanning but it is important to note that the NURBS-based surfaces have been suitable from the triangulated surface models to product the relevant control curve. During the NURBS- based surface description each control points are special (W) which only locally influences the curve's editing. The rational based theory of the curve and surface description (P. Radhakrishnan, 2008) és (G. Farin, 2002) described as an interpolation, where the direction of continuous curves matching with weighted points.

$$P = (W_i X_i , W_i Y_i , W_i Z_i , W_i)\tag{4.}$$

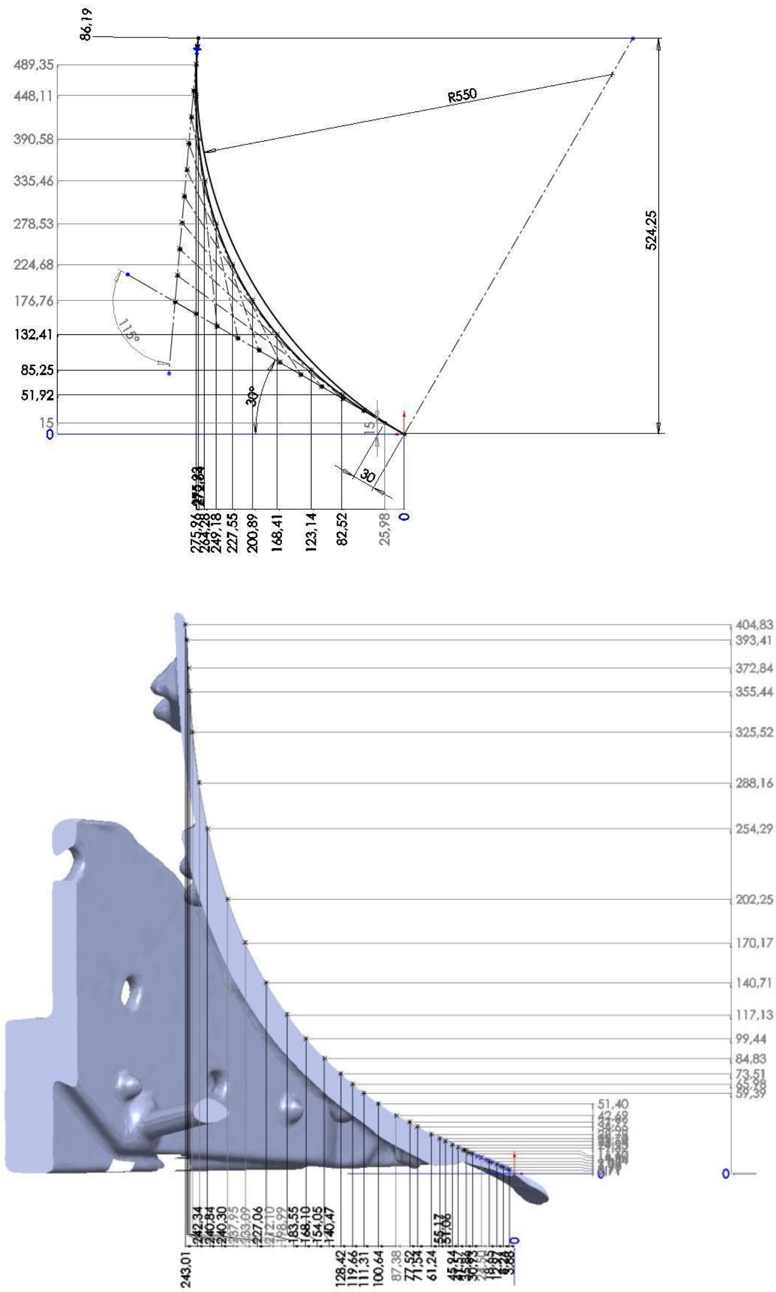

Fig. 7. The point cloud

Control curve editing

Based on the mouldboard's control curve can define the mixing, rotating and pulverizing (Bánházi J., 1984). The assistant components are turning around the control curve. At the case of culture mouldboards according to the editorial principles the mouldboard is located at 2/3. The plain engraving created here, gives the line of the control curve. On the left side of the 7th picture there is the edited, on the right side there is the scanned mouldboard's control curve's point recording. As the mouldboards have got continuously curved surfaces, the control curve can be described with second instance polynoms.

In the 8th picture are shown the polynomials are fitted to the points which are recorded in the surface. The diagram shows that the **horizontal** axis L (deepness of the parabola) and the **vertical** axis H (height of the parabola). When editing the mouldboard, the parabola of the control curve is characterized by with these parameters.

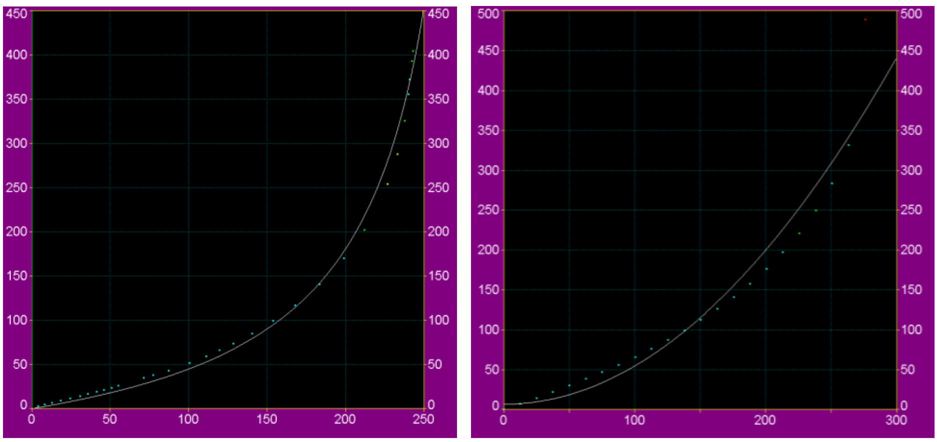

Fig. 8. The control curves from scanned and edited mouldboard

To fitting the polynom we are using 100-100 points and 20 are control points all of these. The two following second instance equation shows that the two cultural designed surfaces can be characterized and comparable with their control curve.

Scanned: $y = 0{,}00585x^2 - 0{,}2548x + 0$; $R^2 = 0{,}9653$

Edited: $y = 0{,}006x^2 - 0{,}3x + 3{,}889$; $R^2 = 0{,}9528$

The differences of the deepness and highness suggests to the planned difference between depth and width of the plowing. The constant parameter of the equation describes the vertical axial position. With coordinate transformations both curve can fit to the 0, so depend on the y angle's rate of change comparable in the two cases.

4. Results

The test's objective results are the control curves describing second instance polynomials, equations. As we know the control curve the mouldboard become reproducible without documents and provide identification of export opportunities.

We proved the applicability of the digitization process with the similarity of the edited and digitized control curves of the mouldboards. The scanned control curve's: $y = 0{,}00585x^2 - 0{,}2548x + 0$ and the edited control curve's: $y = 0{,}006x^2 - 0{,}3x + 3{,}889$ character is similar.

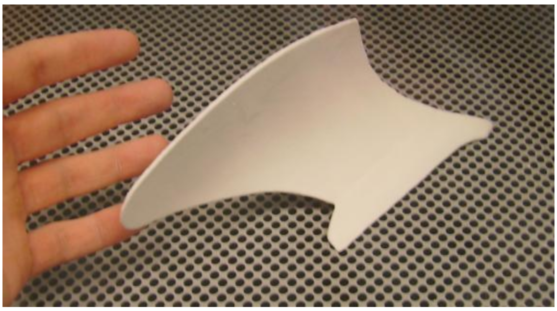

Fig. 9. Scale-modell of the plow

For the mouldboards analysis and development we created a new modeling method during the test. Currently the system is able to semi-automatic process. A quick analysis is possible with it.

To complete the research work we created the digitized mouldboard's realistic model at M1: 5 scale, it can be seen in the 9th picture.

Conclusions

This form of usage of the digitization process seems to be the optimal solution to product geometry of free surfaces like the mouldboard's surface.

The used method seems suitable to describe each control curves which is not a self-serving process, but also may be a well-written key for solving review and improvement problems. Taking this advantage it can be used during the operation monitoring and the abrasion rates are detectable along the surface. These mouldboards could be re-planable as the results of these improvements.

The further development of the used method could be the basis of optimization tasks based on genetic algorithm work surfaces.

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WIRELESS SENSOR NETWORK AD HOC MEASUREMENT

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1. Introduction

The latest infocommunication technology systems extend our measurement possibilities. In our Institute we studied wireless sensor network for different applications. Wireless sensor network is a new concept in measurement. Small motes consist of power source, microcontroller, sensors and RF communication. They can measure the real world parameters and forward them into a data center. What is it good for?

Using wireless sensor network we are able to measure

- in big area,
- for a long time,
- numerous types of parameters of real world environment.

The RF transmission uses special low energy protocol. ZigBee (IEEE 802.15.4 standard) is designed for low bandwidth communication. Measuring 5 parameters with 16 bit accuracy equals 10 bytes of information. Sending the parameters once per seconds needs very low bandwidth. Because of low energy the communication range is quite short. Depending on the RF chip and the amplifier the range can be some 10 meters, or some 100 meters.

As figure 1 shows the node consists all of the components for measuring, processing and sending the phisical world parameters. The power source is usually 2 peaces of AA batteries. If charging is possible, we can use chargeble batteries. Batteries have the adventage of having a higher voltage level, so the RF communication range is bigger than in case of charging systems.

Microcontroller runs at some MHz that is enough to process ADC (Analog Digital Converters) and control the communication. Mote uses ADC to convert the sensor values into digital bytes. The mother board consists of all of the infrastructural components. Sensors are another peripherial extension board. So you can choose a sensor board with neccesary sensors or simply use ADC converters with external sensors (for example special chemistry detectors).

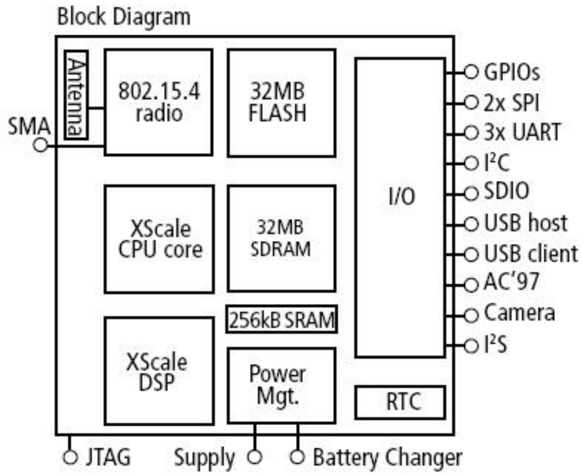

Fig. 1. Block diagram of a wireless sensor network node

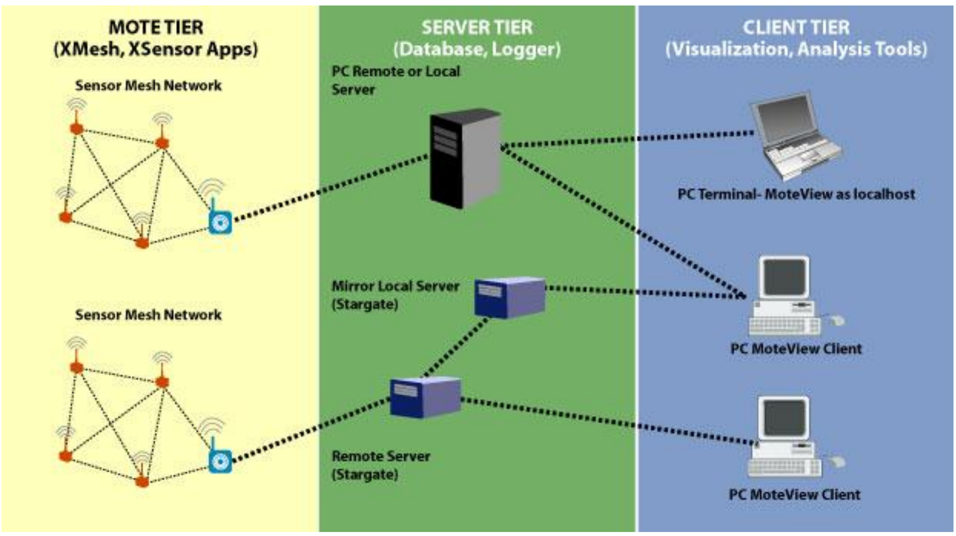

Fig. 2. Wireless sensor network architecture

Figure 2 shows a tipical wireless sensor architecture. The small blue circle symbolises a mote. As mentioned earlier the mote is able to measure and send information. Because of limited RF range, the mote sends the information only to the closest neighbour. When neighbour receives the packet it sends it to the next neighbour until the packet arrives to the data center. The route of the data packet depends the topology of the current network. Usually there are many available routes to the data center. This makes wireless sensor networks very robust. Despite of one mote being crashed (for example due to low voltage) the rest of the network is still able to measure and communicate.

In the data center the measured values are stored in a database. The database can be any SQL storage. Our system uses Postgree SQL. The tables store the phisical values and some additional information, for example date and time of measurement, moteID (name of the mote), voltage level of the mote, RF signal strength. Storing the values in a SQL database has many advantages:

- SQL servers can store large quantities of information (for example, measuring 100 points for a year)
- There are many tools to process data in SQL databases
- There are capabilities of remote access.

Through the internet, we can reach the measurement information from any place of the world. This is a good way to share the measurement results.

Advantages of wireless sensor network measurement:

- using ad hoc network (no wires, no installation)
- collect information from a wide range (many places)
- long time measuring (months, years)

Measuring

Our Institute planned the measurent of the temperature of a lecturing hall (Figure 3).

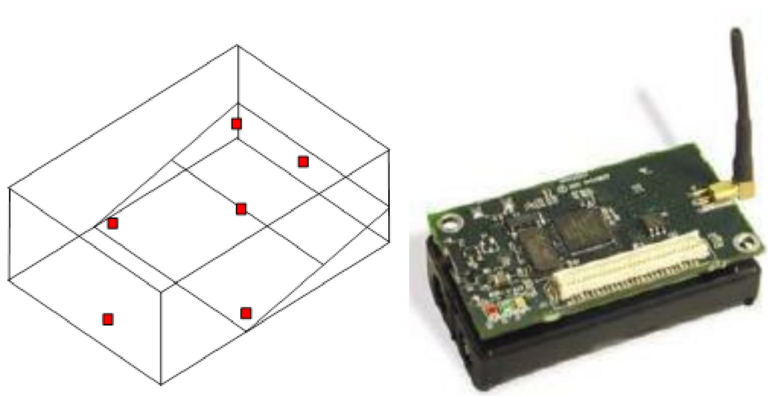

Fig. 3. Positions of motes in the hall, and a photo of a mote

This measure represents the advantage of using wireless sensor network. After placing the motes, the network is ready for measuring. We would like to demonstrate the dependecy of temperature and vertical position.

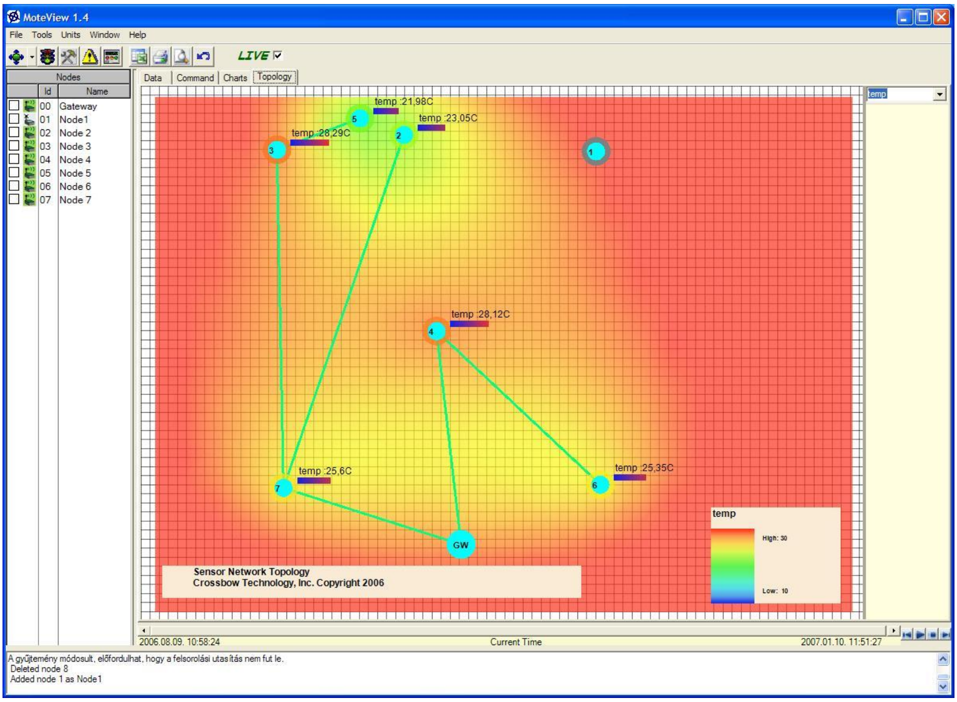

Fig. 4. Result of hall temperature measurement

As figure 4 shows every point has a different temperature. As we expected the lower points have lower temperature while points in the end of hall are very warm. Students in 28 degree Celsius are not able to listen. Optimising the heating system can improve their concentration and in addition reduce the energy consumption.

The old heating controllers have just a few sensors. Using wireless sensor network we can get much more detailed information about a building's temperature.

Picture 4 shows the MoteView application. On the left pane there is a mote list. The colour of the mote shows its status: it is green when the mote have recently received a message. In case of a dead mote first it turns yellow, then red.

In the main screen there is a „map” of motes. It is not a real map, these motes don't have GPS or any other positioning system. The motes can be placed on the map by drag and drop, using the mouse. By placing the motes correctly on the map tab we can see level colouring just like on a traditional map's height levels. There are other tabs to check all detail information about wireless sensor network.

On the map tab we can check the radio connetions beetwen motes. For example only mote7 and mote4 are connected directly to the gateway. Other motes send the information through them. The longest route is mote5-mote3-mote7-gateway. Ad hoc topology is a big advantage of wireless sensor network as they enable self management - one doesn't have to configure the network connections, it chooses the best possible routing.

Conclusion

There are many new technologies among measurement systems. Sensor technology also developes rapidly. Sensors are getting each time smaller and smarter. The latest sensors have temperature compensation and automated calibration.

Wireless sensor networks can be very useful in many applications. In agriculture (quite big area), HVAC (heating, ventilation, and air conditioning) many measuring points in a building using this technology opens a new way of thinking. We are able to measure in much more detail as before. Optimising the energy consumption leads towards green engineering.

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