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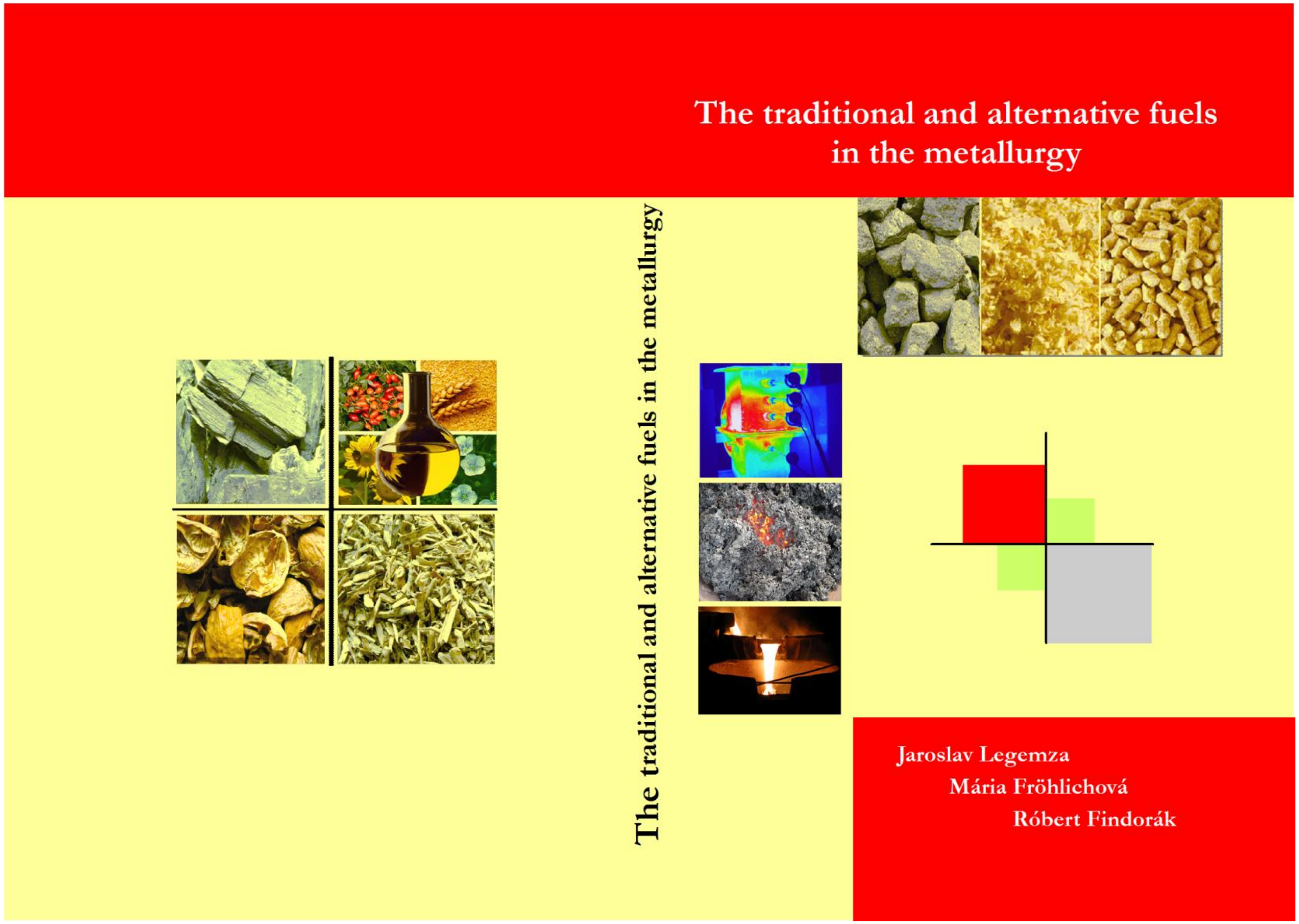

The traditional and alternative fuels
in the metallurgy

The traditional and alternative fuels in the metallurgy

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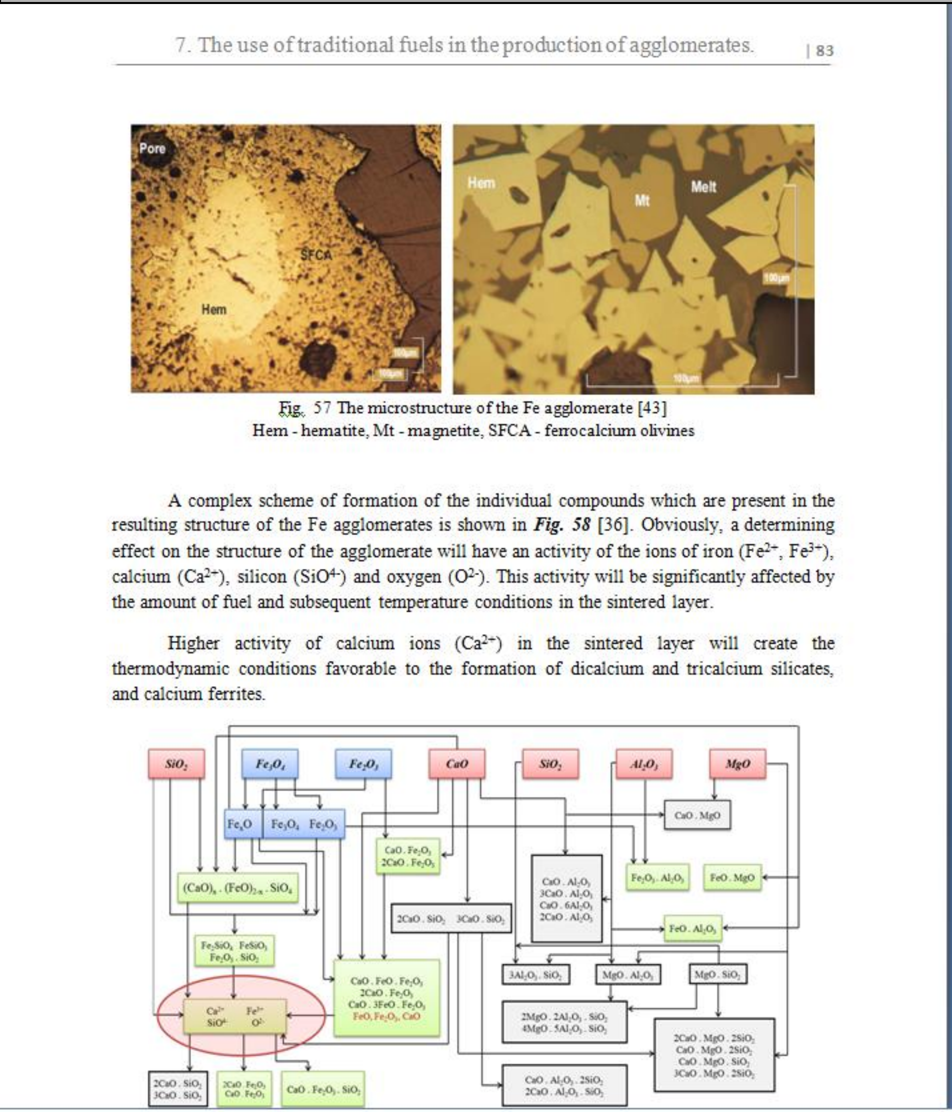
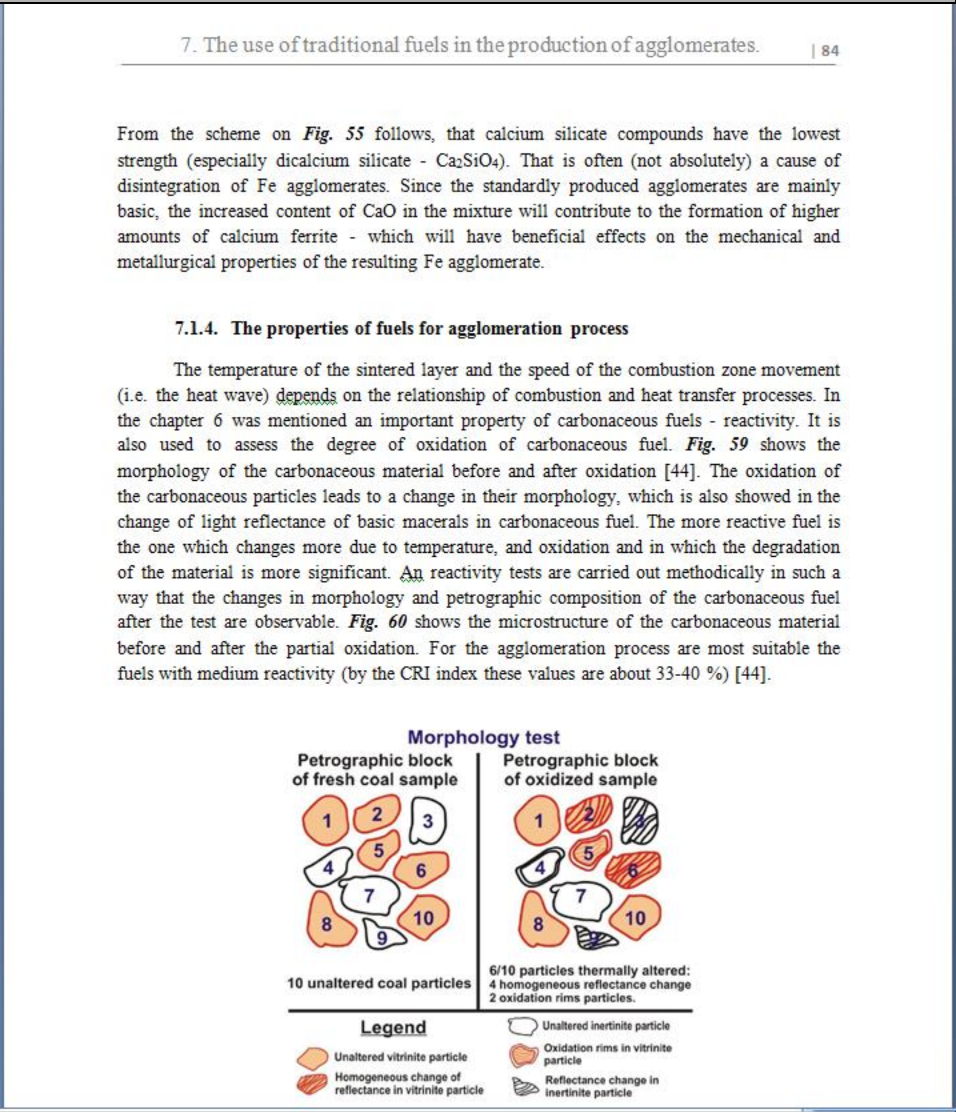


7. The use of traditional fuels in the production of agglomerates. | 83

Fig. 57 The microstructure of the Fe agglomerate [43]
Hem - hematite, Mt - magnetite, SFCA - ferrocalcium olivines

A complex scheme of formation of the individual compounds which are present in the resulting structure of the Fe agglomerates is shown in ***Fig. 58*** [36]. Obviously, a determining effect on the structure of the agglomerate will have an activity of the ions of iron (Fe^{2+}, Fe^{3+}), calcium (Ca^{2+}), silicon (SiO^{4-}) and oxygen (O^{2-}). This activity will be significantly affected by the amount of fuel and subsequent temperature conditions in the sintered layer.

Higher activity of calcium ions (Ca^{2+}) in the sintered layer will create the thermodynamic conditions favorable to the formation of dicalcium and tricalcium silicates, and calcium ferrites.



7. The use of traditional fuels in the production of agglomerates. | 84

From the scheme on ***Fig. 55*** follows, that calcium silicate compounds have the lowest strength (especially dicalcium silicate - Ca_2SiO_4). That is often (not absolutely) a cause of disintegration of Fe agglomerates. Since the standardly produced agglomerates are mainly basic, the increased content of CaO in the mixture will contribute to the formation of higher amounts of calcium ferrite - which will have beneficial effects on the mechanical and metallurgical properties of the resulting Fe agglomerate.

7.1.4. The properties of fuels for agglomeration process

The temperature of the sintered layer and the speed of the combustion zone movement (i.e. the heat wave) depends on the relationship of combustion and heat transfer processes. In the chapter 6 was mentioned an important property of carbonaceous fuels - reactivity. It is also used to assess the degree of oxidation of carbonaceous fuel. ***Fig. 59*** shows the morphology of the carbonaceous material before and after oxidation [44]. The oxidation of the carbonaceous particles leads to a change in their morphology, which is also showed in the change of light reflectance of basic macerals in carbonaceous fuel. The more reactive fuel is the one which changes more due to temperature, and oxidation and in which the degradation of the material is more significant. An reactivity tests are carried out methodically in such a way that the changes in morphology and petrographic composition of the carbonaceous fuel after the test are observable. ***Fig. 60*** shows the microstructure of the carbonaceous material before and after the partial oxidation. For the agglomeration process are most suitable the fuels with medium reactivity (by the CRI index these values are about 33-40 %) [44].

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Zníženie energetickej a environmentálnej záťaže výroby železorudného aglomerátu náhradou fosilného paliva odpadnou biomasou APVV-16-0513

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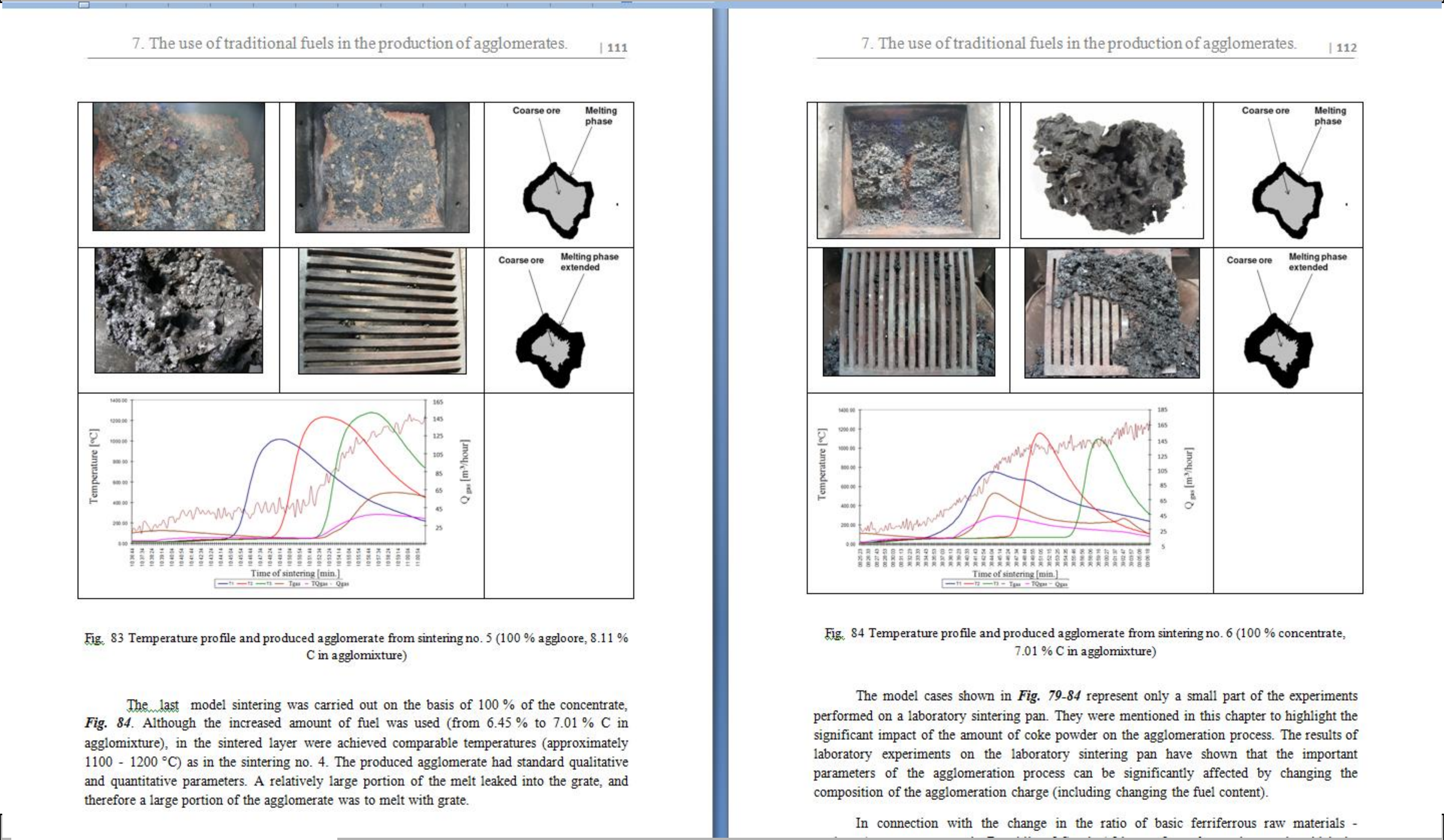

Fig. 83 Temperature profile and produced agglomerate from sintering no. 5 (100 % aggloore, 8.11 % C in agglomixture)

The last model sintering was carried out on the basis of 100 % of the concentrate, ***Fig. 84***. Although the increased amount of fuel was used (from 6.45 % to 7.01 % C in agglomixture), in the sintered layer were achieved comparable temperatures (approximately 1100 - 1200 °C) as in the sintering no. 4. The produced agglomerate had standard qualitative and quantitative parameters. A relatively large portion of the melt leaked into the grate, and therefore a large portion of the agglomerate was to melt with grate.

Fig. 84 Temperature profile and produced agglomerate from sintering no. 6 (100 % concentrate, 7.01 % C in agglomixture)

The model cases shown in ***Fig. 79-84*** represent only a small part of the experiments performed on a laboratory sintering pan. They were mentioned in this chapter to highlight the significant impact of the amount of coke powder on the agglomeration process. The results of laboratory experiments on the laboratory sintering pan have shown that the important parameters of the agglomeration process can be significantly affected by changing the composition of the agglomeration charge (including changing the fuel content).

In connection with the change in the ratio of basic ferriferrous raw materials -

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Zníženie energetickej a environmentálnej záťaže výroby železorudného aglomerátu náhradou fosilného paliva odpadnou biomasou APVV-16-0513

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METALURGIE

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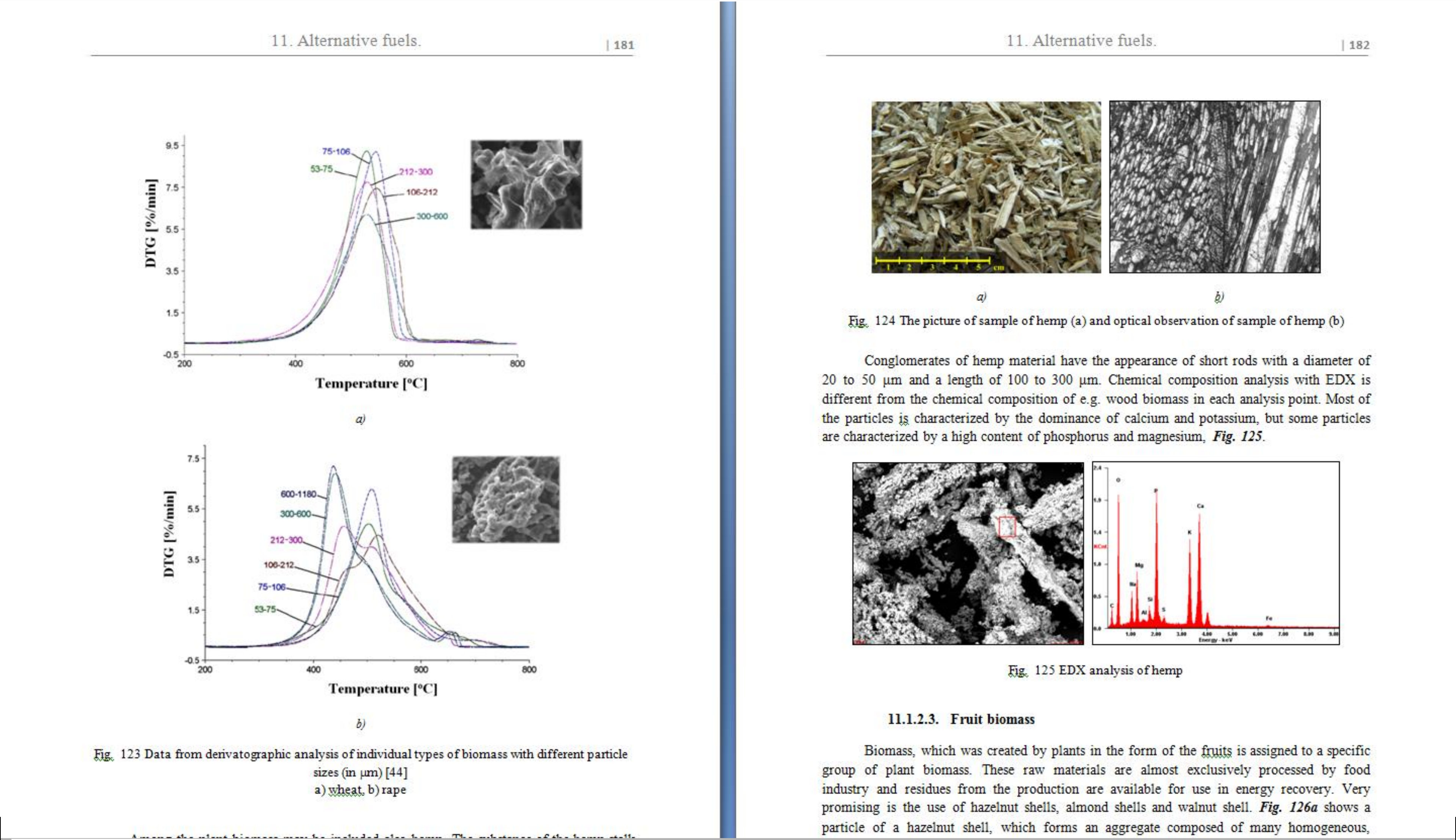


a)

b)

Fig. 123 Data from derivatographic analysis of individual types of biomass with different particle sizes (in µm) [44]
a) wheat, b) rape

a) b)

Fig. 124 The picture of sample of hemp (a) and optical observation of sample of hemp (b)

Conglomerates of hemp material have the appearance of short rods with a diameter of 20 to 50 µm and a length of 100 to 300 µm. Chemical composition analysis with EDX is different from the chemical composition of e.g. wood biomass in each analysis point. Most of the particles is characterized by the dominance of calcium and potassium, but some particles are characterized by a high content of phosphorus and magnesium, ***Fig. 125***.

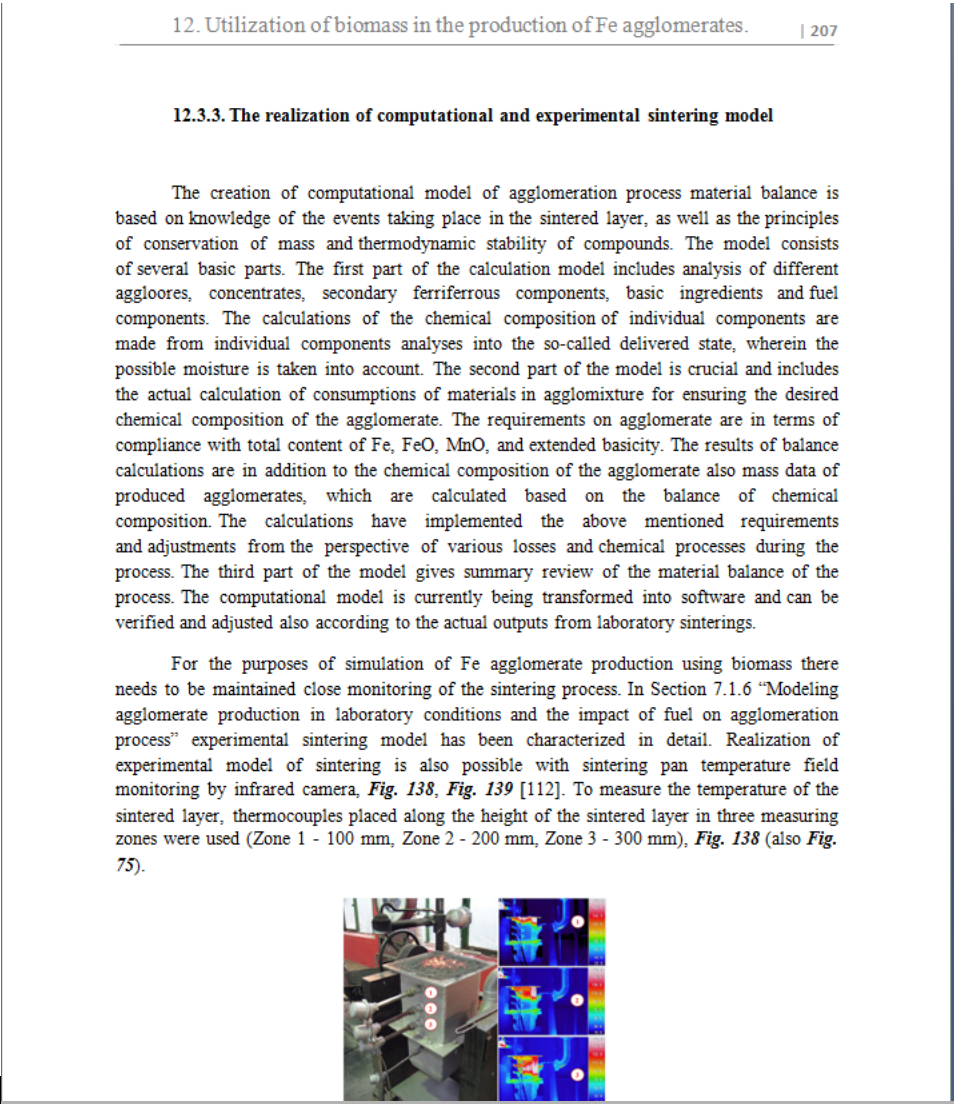
Fig. 125 EDX analysis of hemp

11.1.2.3. Fruit biomass

Biomass, which was created by plants in the form of the fruits is assigned to a specific group of plant biomass. These raw materials are almost exclusively processed by food industry and residues from the production are available for use in energy recovery. Very promising is the use of hazelnut shells, almond shells and walnut shell. ***Fig. 126a*** shows a particle of a hazelnut shell, which forms an aggregate composed of many homogeneous,

Zníženie energetickej a environmentálnej záťaže výroby železorudného aglomerátu náhradou fosilného paliva odpadnou biomasou APVV-16-0513

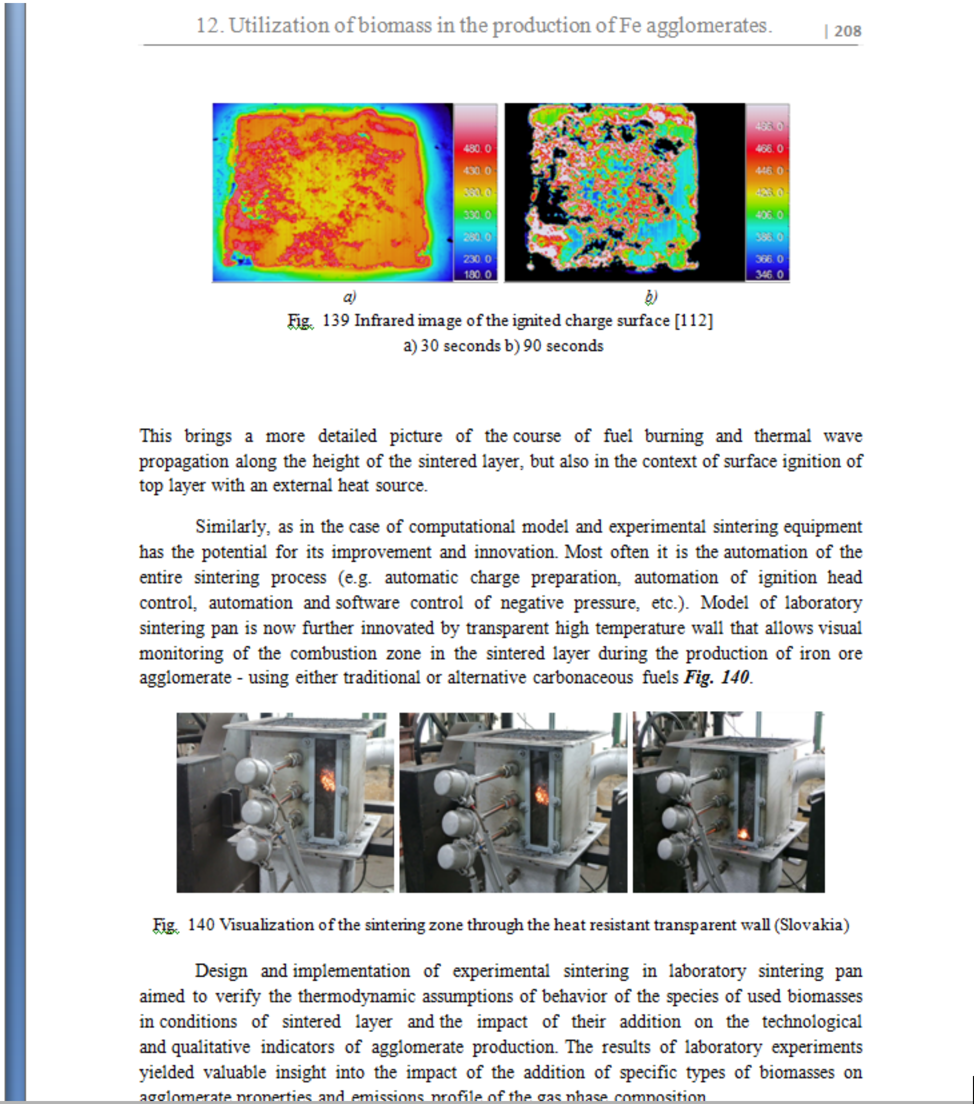
Monografia „The traditional and alternative fuels in the metallurgy“.



12.3.3. The realization of computational and experimental sintering model

The creation of computational model of agglomeration process material balance is based on knowledge of the events taking place in the sintered layer, as well as the principles of conservation of mass and thermodynamic stability of compounds. The model consists of several basic parts. The first part of the calculation model includes analysis of different aggloores, concentrates, secondary ferriferrous components, basic ingredients and fuel components. The calculations of the chemical composition of individual components are made from individual components analyses into the so-called delivered state, wherein the possible moisture is taken into account. The second part of the model is crucial and includes the actual calculation of consumptions of materials in agglomixture for ensuring the desired chemical composition of the agglomerate. The requirements on agglomerate are in terms of compliance with total content of Fe, FeO, MnO, and extended basicity. The results of balance calculations are in addition to the chemical composition of the agglomerate also mass data of produced agglomerates, which are calculated based on the balance of chemical composition. The calculations have implemented the above mentioned requirements and adjustments from the perspective of various losses and chemical processes during the process. The third part of the model gives summary review of the material balance of the process. The computational model is currently being transformed into software and can be verified and adjusted also according to the actual outputs from laboratory sinterings.

For the purposes of simulation of Fe agglomerate production using biomass there needs to be maintained close monitoring of the sintering process. In Section 7.1.6 “Modeling agglomerate production in laboratory conditions and the impact of fuel on agglomeration process” experimental sintering model has been characterized in detail. Realization of experimental model of sintering is also possible with sintering pan temperature field monitoring by infrared camera, ***Fig. 138***, ***Fig. 139*** [112]. To measure the temperature of the sintered layer, thermocouples placed along the height of the sintered layer in three measuring zones were used (Zone 1 - 100 mm, Zone 2 - 200 mm, Zone 3 - 300 mm), ***Fig. 138*** (also ***Fig. 75***).



a) *b)*

Fig. 139 Infrared image of the ignited charge surface [112]
a) 30 seconds b) 90 seconds

This brings a more detailed picture of the course of fuel burning and thermal wave propagation along the height of the sintered layer, but also in the context of surface ignition of top layer with an external heat source.

Similarly, as in the case of computational model and experimental sintering equipment has the potential for its improvement and innovation. Most often it is the automation of the entire sintering process (e.g. automatic charge preparation, automation of ignition head control, automation and software control of negative pressure, etc.). Model of laboratory sintering pan is now further innovated by transparent high temperature wall that allows visual monitoring of the combustion zone in the sintered layer during the production of iron ore agglomerate - using either traditional or alternative carbonaceous fuels ***Fig. 140***.

Fig. 140 Visualization of the sintering zone through the heat resistant transparent wall (Slovakia)

Design and implementation of experimental sintering in laboratory sintering pan aimed to verify the thermodynamic assumptions of behavior of the species of used biomasses in conditions of sintered layer and the impact of their addition on the technological and qualitative indicators of agglomerate production. The results of laboratory experiments yielded valuable insight into the impact of the addition of specific types of biomasses on agglomerate properties and emissions profile of the gas phase composition.

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Zníženie energetickej a environmentálnej záťaže výroby železorudného aglomerátu náhradou fosilného paliva odpadnou biomasou APVV-16-0513

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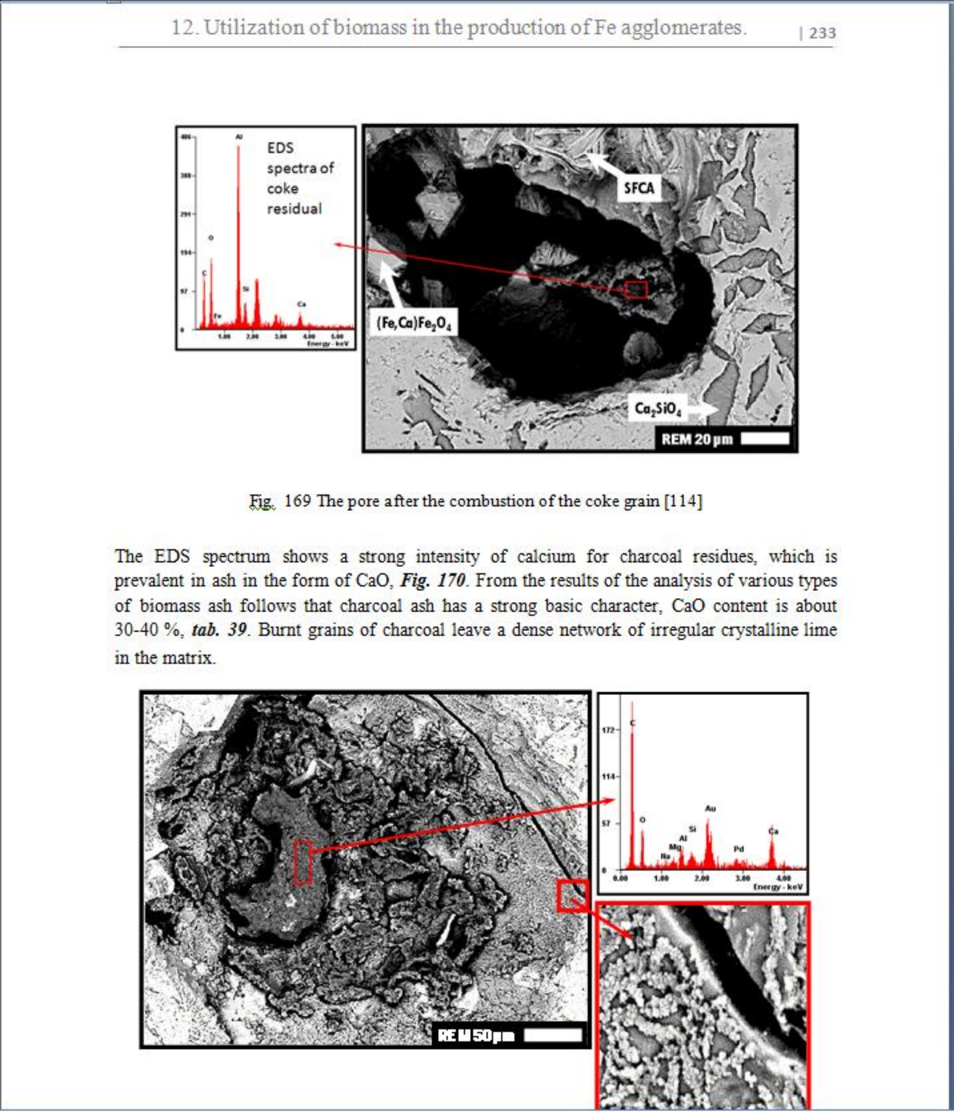
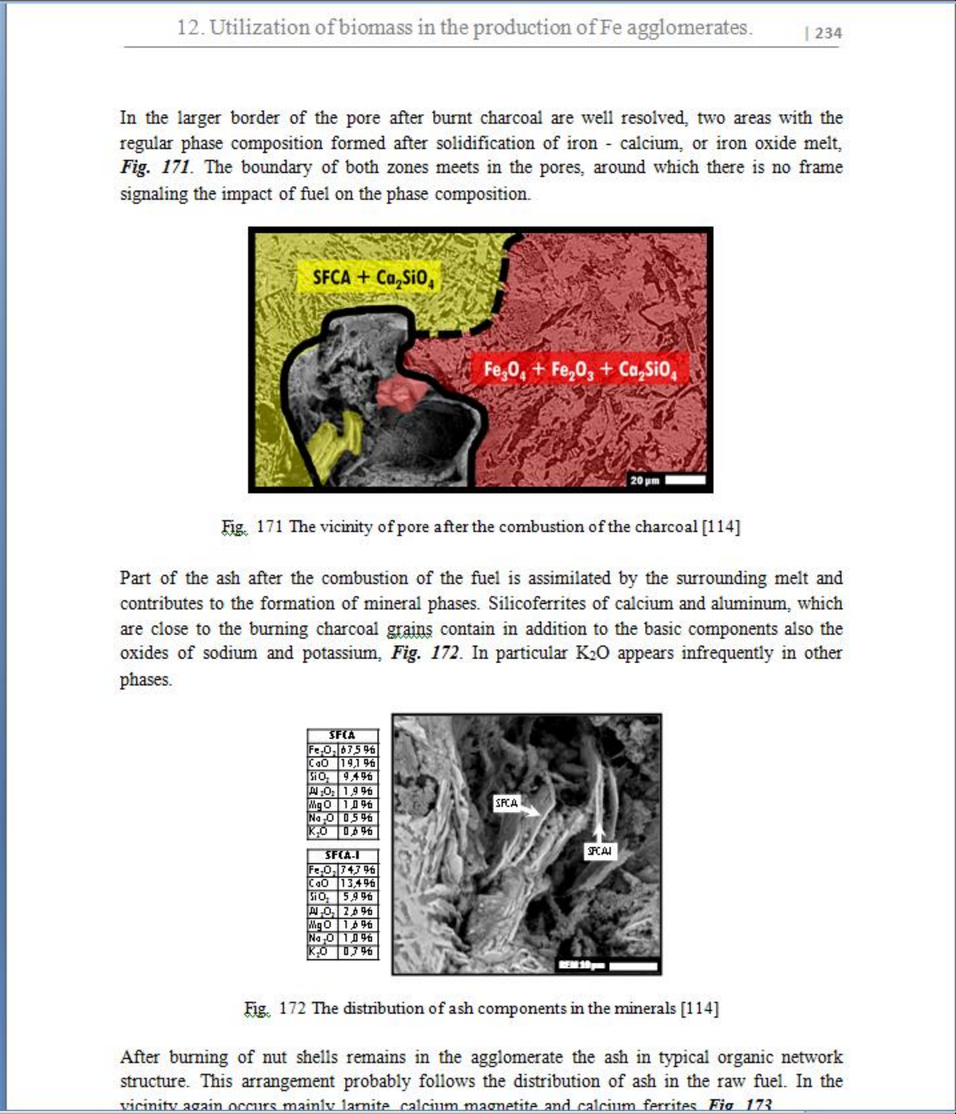


Fig. 169 The pore after the combustion of the coke grain [114]

The EDS spectrum shows a strong intensity of calcium for charcoal residues, which is prevalent in ash in the form of CaO, ***Fig. 170***. From the results of the analysis of various types of biomass ash follows that charcoal ash has a strong basic character, CaO content is about 30-40 %, ***tab. 39***. Burnt grains of charcoal leave a dense network of irregular crystalline lime in the matrix.



In the larger border of the pore after burnt charcoal are well resolved, two areas with the regular phase composition formed after solidification of iron - calcium, or iron oxide melt, ***Fig. 171***. The boundary of both zones meets in the pores, around which there is no frame signaling the impact of fuel on the phase composition.

Fig. 171 The vicinity of pore after the combustion of the charcoal [114]

Part of the ash after the combustion of the fuel is assimilated by the surrounding melt and contributes to the formation of mineral phases. Silicoferrites of calcium and aluminum, which are close to the burning charcoal grains contain in addition to the basic components also the oxides of sodium and potassium, ***Fig. 172***. In particular K_2O appears infrequently in other phases.

SFCA	
Fe_2O_3	67,5 %
CaO	19,1 %
SiO_2	9,4 %
Al_2O_3	1,9 %
MgO	1,0 %
Na_2O	0,5 %
K_2O	0,6 %

SFCA-I	
Fe_2O_3	74,7 %
CaO	13,4 %
SiO_2	5,9 %
Al_2O_3	2,6 %
MgO	1,6 %
Na_2O	1,0 %
K_2O	0,7 %

Fig. 172 The distribution of ash components in the minerals [114]

After burning of nut shells remains in the agglomerate the ash in typical organic network structure. This arrangement probably follows the distribution of ash in the raw fuel. In the vicinity again occurs mainly larnite, calcium magnetite and calcium ferrites, *Fig. 173*.

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Zníženie energetickej a environmentálnej záťaže výroby železorudného aglomerátu náhradou fosilného paliva odpadnou biomasou APVV-16-0513

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METALURGIE

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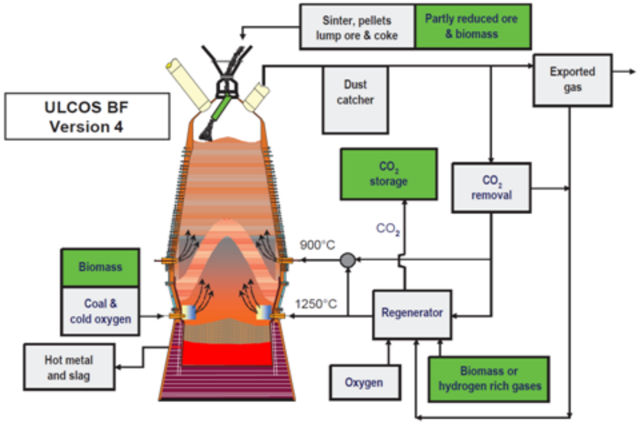


Fig. 190 The project of pig iron production in the modified blast furnace - ULCOS-BF [116]

In the project of advanced DRI shaft furnace (type Midrex) are currently developed mathematical models and simulations, in which hydrogen, produced by electrolysis of water, would be used for iron oxide reduction. This new technology has the potential to reduce CO_2 emissions by up to 80-90 % in comparison with blast furnace. The project for Fe oxide pellets reduction with hydrogen in laboratory conditions is called Reductor. This technology has not only environmental but also technological benefits, because the reduction with hydrogen is carried out at temperatures of about 800-850 °C and is kinetically faster and more efficient in comparison with carbon reductants (CO and C). In ***Fig. 191*** are listed microstructures of products of reduction with hydrogen at 800 °C [118].

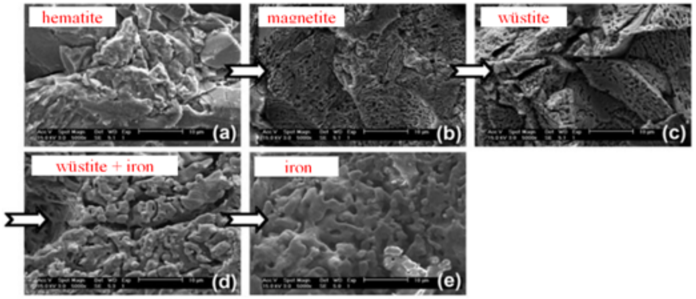
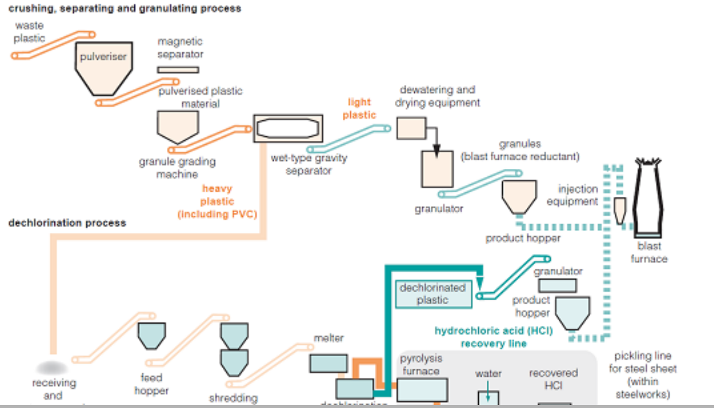


Fig. 191 Microstructure of products after reduction with hydrogen at 800 °C [118]
a) input Fe pellet b - d) reduction intermediates, e) reduced Fe

Prospective alternative fuels for BF in the future may be also plastics. Globally, plastics are used in many industrial applications - including metallurgy. The most advanced and developed technology using plastics in metallurgy is in Japan, where, after particle size modification, the plastics are injected into the tuyeres of the BF, ***Fig. 192***. At present, the technologies of plastics dechlorination before injection into the BF are being developed in Japan [119].



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Zníženie energetickej a environmentálnej záťaže výroby železorudného aglomerátu náhradou fosilného paliva odpadnou biomasou APVV-16-0513

ÚSTAV
METALURGIE