REPORT:
Study of a Sample of
Raw Iron Ore Pellets

with MAYA Elemental Laser Analyzer
in a Stream Mode

1. Goal of the Study.

Evaluating the applicability of the laser optical analyzer MAYA automated control of flux dosage into iron ore charge in order to stabilize the basicity of the iron ore pellets and to control the roasting parameters.

2. Technical task.

Determining the content of Fe (overall), Si and Ca in iron ore pellets, in real-time mode, on a conveyor belt, without sampling. Controlled parameters:

Element	Nominal content, %
Fe	62,0 – 66,0
SiO_2	4,5 – 6,5
CaO	0,4 – 0,8
MgO	0,1 – 0,8

3. Description of the Samples.

3.1. Description of the Batch.

For this test, there was a set of samples of unprocessed iron ore pellets provided. This set consist of 8 samples of unprocessed iron ore pellets, which were taken from the *pelletization of the concentrate* segment of a conveyor bet.

Net mass of each sample is 2.3 kg. Each sample was packed in a hermetically sealed 1L plastic container.

The material is present in the form of moist spherical and oval black pellets, diameter 10-12 mm. The material is loose and friable, easily breaks into finely-dispersed paste (Pic. 1.).

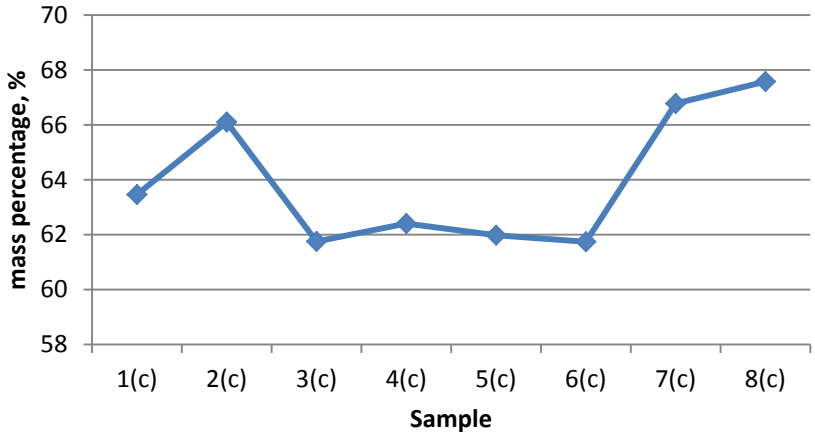
Picture 1. Unprocessed iron ore pellet.

3.2. Elemental composition of the provided samples.

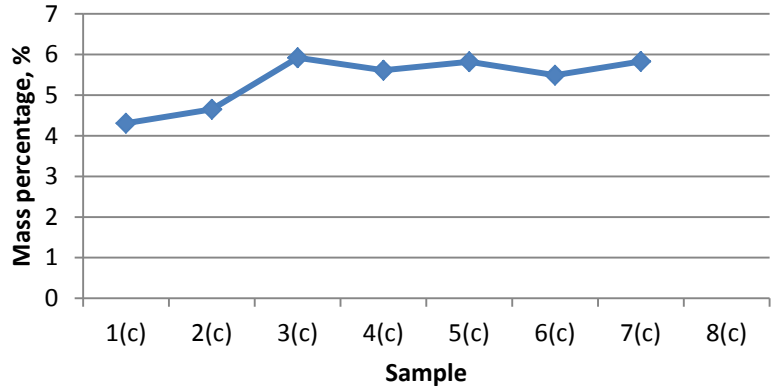
Sample #	Sample name	Analysis type	Mass content %		
			Fe	SiO2	CaO
1(c)	Unprocessed pellet	ICP	63.46	4.31	2.70
2(c)	Unprocessed pellet	ICP	66.10	4.65	0.81
3(c)	Unprocessed pellet	ICP	61.75	5.92	3.49
4(c)	Unprocessed pellet	ICP	62.40	5.61	3.70
5(c)	Unprocessed pellet	ICP	61.97	5.82	3.54
6(c)	Unprocessed pellet	ICP	61.73	5.49	4.23
7(c)	Unprocessed pellet	ICP	66.77	5.83	0.44
8(c)	Unprocessed pellet	ICP	67.57	5.68	0.49

3.3. Range of concentrations of the elements within the analyzed batch of samples

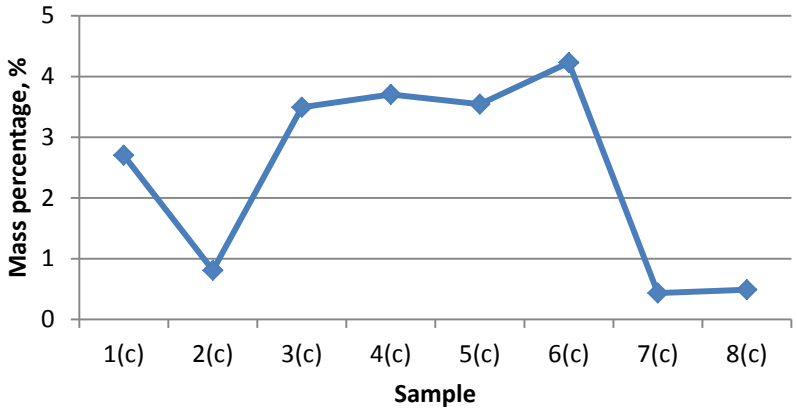
3.3.1.Range of values (Fe) in the samples of unprocessed pellets



3.3.2. Range of values (SiO_2) in the samples of unprocessed pellets



3.3.3. Range of values (CaO) in the samples of unprocessed pellets



Element	Range, indicated in the Technical Task (%)	Range in the provided samples (%)
Fe	**4,0**	**6,06**
SiO2	**2,0**	**1,61**
CaO	**0,4**	**3,80**
MgO	**0,7**	**N/A**

Table 1. Comparison of the ranges of change of concentration of the specified elements.

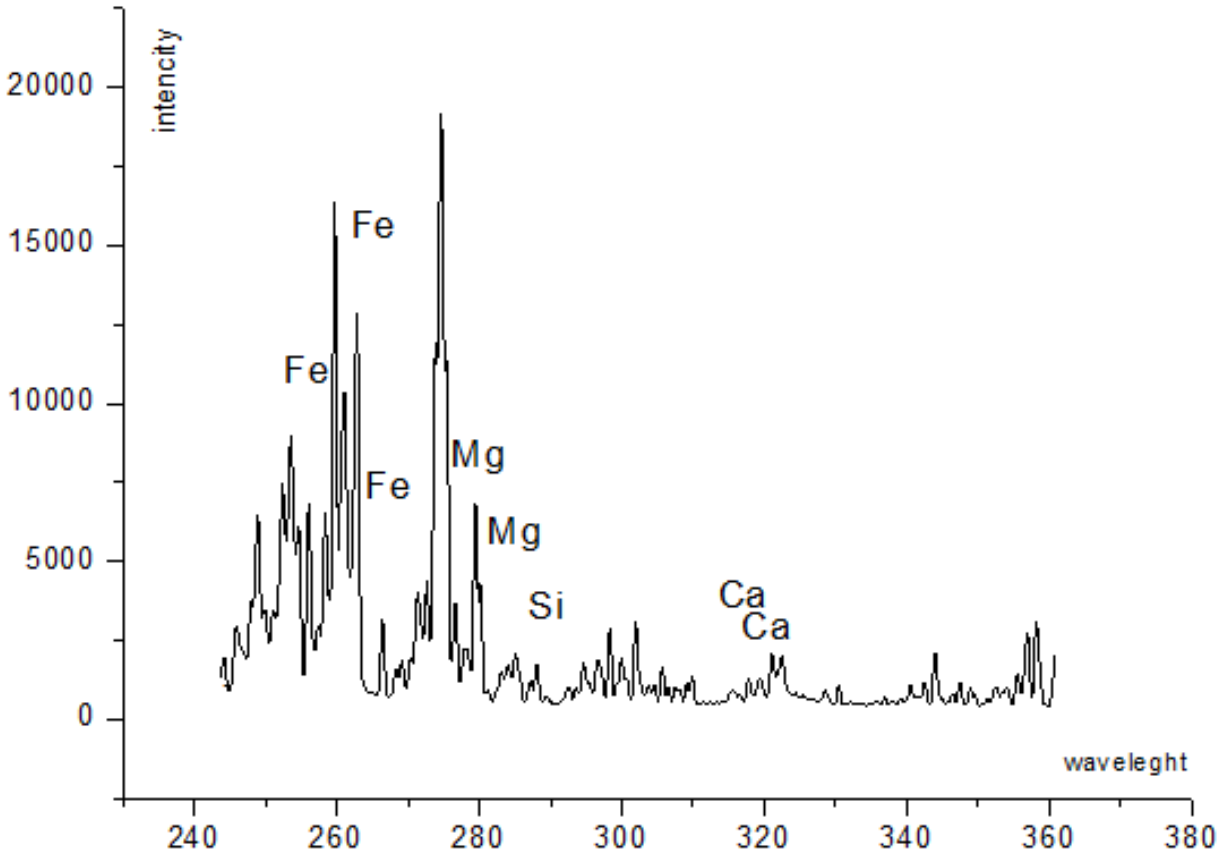
There are 8 samples in the analyzed batch. The batch's range of change of Fe, SiO_2, CaO concentrations exceeds the range of concentrations of Fe, SiO2 and CaO stated in the technical questionnaire; yet, it does not uniformly span the whole interval of the possible concentrations. Therefore, at this stage, it is possible to develop calibrating algorithms

only for the general evaluation of the possibility of achieving the necessary accuracy in real-life conveyor belt applications – in real-time mode, without sampling.

4. The technique of the experiment

We used a lab simulator of a conveyor belt to study the samples. Each sample was scanned with a necessary number of laser impulses, sent from ~30-40cm distance, in order to accumulate sufficient data. A UV (λ = 250-370 nm) was used to obtain the spectral data.

4.1. Characteristics of the optical spectra.



Pic 2. Typical optical spectrum of unprocessed pelletized iron ore

The spectrum pictured above demonstrates that the studied material has a unique spectral image and can therefore be easily recognized.

Optical spectra of the provided samples span the entire range for detecting all the elements of interest (Fe, Si and Ca), as well as Mg. Each spectrum contains clear and unmistakably identifiable characteristic Fe, Si, Ca, Mg peaks.

4.2. Quantitative analytical algorithm

We used ICP elemental analysis as a basis for the quantitative analytical algorithm. The following data correlations between LIBS and ICP analyses were obtained:

4.2.1. Total Fe Correlation

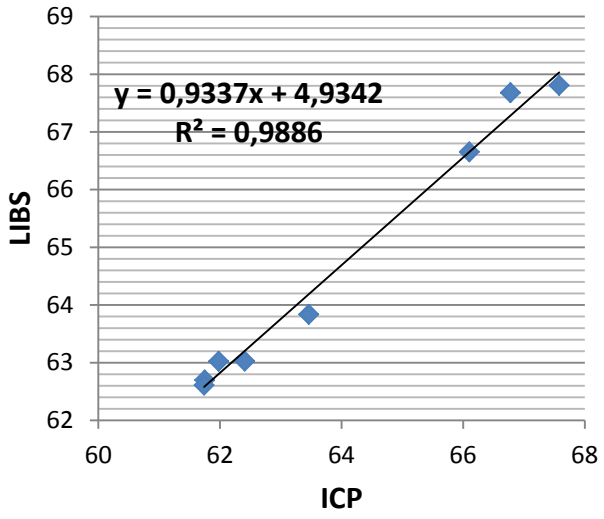


Table 2: LIBS and ICP Fe data correlation

4.2.2.SiO_2 Correlation

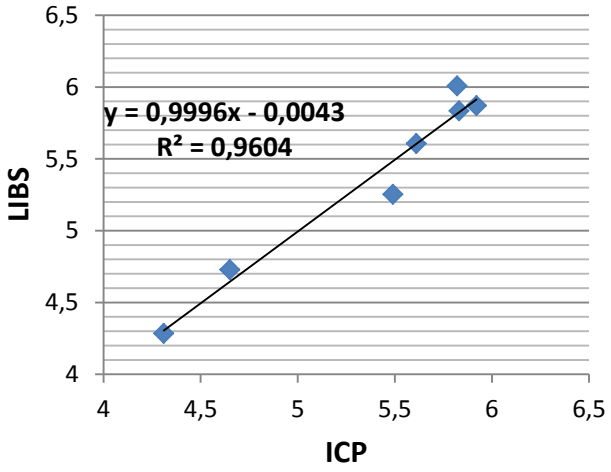
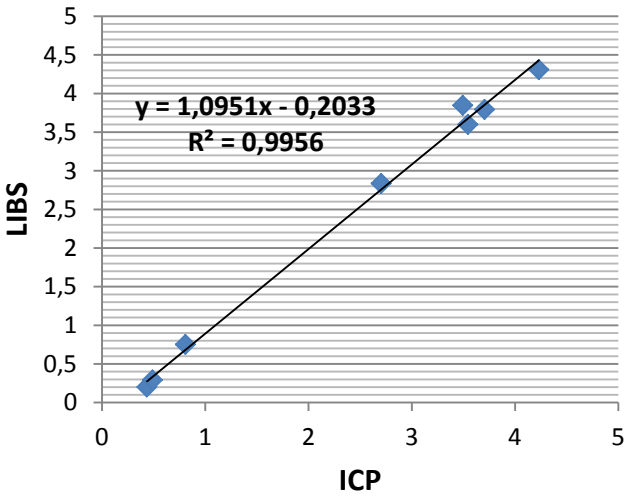


Table 3: LIBS and ICP Si data correlation

4.2.3. CaO Correlation



4.2.4. CaO/SiO_2 correlation

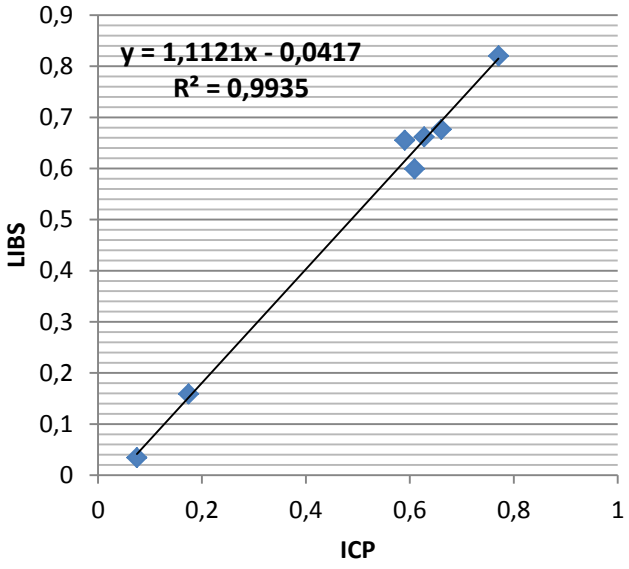


Table 4.LIBS and ICP basicity data correlation.

5. Final table of accuracy parameters

Accuracy parameters		
Element, material	Correlation, R^2	Mean absolute deviation from the ICP data, %
Fe total	0,9886	0,25
CaO	0,9956	0,15
SiO_2	0,9604	0,08
CaO/SiO_2	0,9935	0,033

6. Conclusions.

1. The conducted experiments have demonstrated the definite feasibility of a quantitative analysis of unprocessed iron ore pellets using Laser-Induced Breakdown Spectroscopy in real-time mode on conveyor belt.
2. Qualitative LIBS analysis has provided convincing results in detecting all the elements of interest. This method of laser-based analysis has a high sensitivity in detecting Mg, Fe, Ca and Si, which is a major advantage over other methods.
3. Quantitative LIBS analysis, which used ICP data on the calibrating samples in order to develop the algorithms, has shown sufficiently good results in detecting Fe, Ca and Si concentration in unprocessed iron ore pellets.
4. The algorithms developed at the current stage have demonstrated that it is definitely possible to achieve good accuracy characteristics when studying unprocessed fluxed iron ore pellets without sample preparation; these algorithms can be used as a base for calibrating algorithms which can be applied at a real-life conveyor belt in real-time mode.
5. When controlling the technological processes (flux dosage, roasting mode), the main characteristics of the analyzer's algorithm (such as the periodicity of the output display, accuracy parameters, threshold values of the controlled parameters etc.) should be coordinated with the parameters which are necessary for solving the control tasks.