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GREEN DENSITY MODELLING OF IRON AND FERROMANGANESE MIXED POWDERS

Cristian SUCIU, George ARGHIR, Ioan PETEAN, Dan FRUNZA, Liviu BRANDUSAN

Abstract: *An experimental study on green density of iron and ferromanganese mixed powders was done. The influence of added Mn up to 15 wt. % to Fe powder on the compressibility has been investigated. Cylindrical specimens of mixed iron powder (DWP400) and ferromanganese powder (FeMn80C20) were made. The samples were bilaterally pressed at 100 to 600 MPa. Pressed samples were analyzed by density measurements and also by numerical method. The density of mixed powders decreases as the manganese content increases, and have the maximum value for a content of 5 wt. % Mn.*
Key words: *density, manganese, iron, simulation.*

1. INTRODUCTION

The production of the manganese alloy steels is the new trend in powder metallurgy industry. Manganese is used because it offers increased hardenability but reduces the compressibility of the powders [1, 2].

The research work presented in this paper is concentrated on the influence of manganese content on the density of mixed iron-manganese powders.

2. EXPERIMENTAL PROCEDURE

The iron powder DWP 400 is mixed with ferromanganese powder FeMn80C20 having particle size less than 63 μm. Chemical compositions of powders is presented in Table 1.

Table 1. Chemical compositions of powders

Powder type	C, %	S, %	Mn, %	O, %	Fe, %
DWP 400	0	0.02	0.13	0.17	balance
FeMn80 C20	2.00	0	balance	0.17	15.84

Powder grain size is presented in Table 2 (according to SR EN 2449). This shows that iron powder tend to be finer in particle size with 28 % under 63 μm and with 24.61 % between 125-250 μm, respectively with 19 % in area 80-100 and 100-125 μm.

Table 2. Particle size distribution of iron powder

Grain size, μm	<63	63-71	71-80	80-100
DWP 400, %	28.09	4.80	3.46	19.23
Grain size, μm	100-125	125-250	250-315	>315
DWP 400, %	19.05	24.61	0.38	0.38

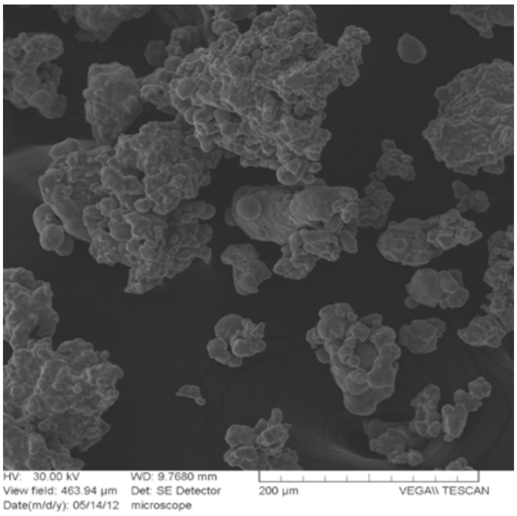
The apparent density (according with SR EN 23923-1: 1998) and flow rate (SR EN ISO 4490: 2008) are listed in Table 3.

Table 3. Apparent density and flow rate of powders

Powder type	Apparent density, g/cm^3	Flow rate, sec/50 g
DWP 400	2.60	43.3
Fe5Mn	2.79	31.0
Fe7Mn	2.80	30.1
Fe9Mn	2.81	29.2
Fe11Mn	2.82	28.3
Fe13Mn	2.85	27.5
Fe15Mn	2.88	26.8

It was observed an increase of apparent density and flow rate with increase of Mn content. Powder with 15 wt. % Mn had highest apparent density and flow rate.

The morphology of used powders was evaluated using a Scanning electron microscope (SEM) Vega Tescan.



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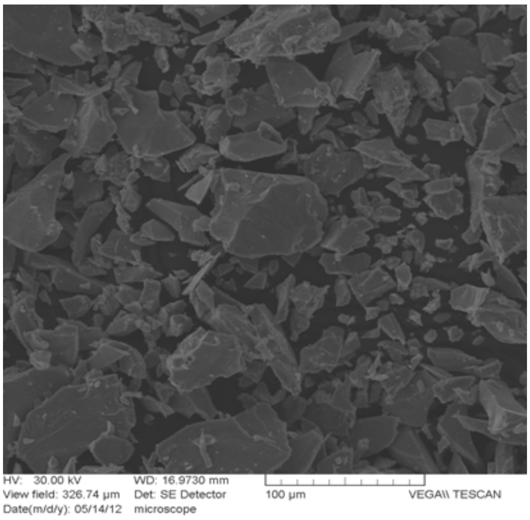

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Fig. 1. SEM images of powders: a) iron powder DWP 400, b) ferromanganese powder FeMn80C20 under 63 μm grain size.

From Figure 1a it can be observed that the Fe powder has irregular morphology. Finally we observed that the average diameter of grains is situated around 80-250 μm. The microstructure ferromanganese observed at average magnification in Fig 1b and reveals polyhedral grains of powders.

For this experiment test samples were prepared using iron powder (DWP 400) mixed with ferromanganese (FeMn80C20) concentrations of 5, 7, 9, 11, 13, 15 wt. % Mn, and milled in a planetary mill for 15 min without lubricant. The bilaterally pressing was done in an 11.285 mm diameter cavity steel die at pressure ranging between 100 to 600 MPa on a tensile compression machine.

After pressing each sample was weighed using a Precisa XT 220A scale with sensitivity of 10^{-5} and after that was measured using a Mitutoyo digital micrometer.

Numerical analysis of the compaction of cylindrical specimens was carried out with Marc AutoForge software.

3. RESULTS AND DISCUSSION

The values of green and relative density of the samples are shown in Table 4. The average green density of specimens was between 4.65 and 6.69 g/cm^3. Green samples with 15 wt. % Mn show the lowest density.

Relative density was calculated with formula:

$$\rho_{relative} = \rho_{green} / \rho_{theoretic}; \qquad (1)$$

where ρ_{green} is the green density of sample, $\rho_{theoretic}$ is the theoretical density of sample.

Table. 4. Green and relative density of samples

Pres, MPa	0	100	200	300	400	500	600
% Mn	5						
ρ_{green}	2.79	4.66	5.45	5.89	6.27	6.44	6.70
ρ_{rel} real	0.36	0.60	0.70	0.75	0.80	0.82	0.86
ρ_{rel} mod	0.36	0.62	0.72	0.78	0.82	0.84	0.84
% Mn	7						
ρ_{green}	2.80	4.66	5.39	5.90	6.20	6.43	6.64
ρ_{rel} real	0.36	0.60	0.69	0.75	0.79	0.82	0.85
ρ_{rel} mod	0.36	0.62	0.72	0.78	0.82	0.84	0.86
% Mn	9						
ρ_{green}	2.81	4.68	5.32	5.85	6.13	6.33	6.63
ρ_{rel} real	0.36	0.60	0.68	0.75	0.79	0.81	0.85
ρ_{rel} mod	0.36	0.62	0.72	0.78	0.82	0.84	0.86
% Mn	11						
ρ_{green}	2.82	4.71	5.37	5.85	6.07	6.31	6.51
ρ_{rel} real	0.36	0.61	0.69	0.75	0.78	0.81	0.84
ρ_{rel} mod	0.36	0.62	0.73	0.78	0.82	0.84	0.84
% Mn	13						
ρ_{green}	2.85	4.63	5.28	5.70	6.02	6.29	6.47
ρ_{rel} real	0.37	0.60	0.68	0.73	0.77	0.81	0.83
ρ_{rel} mod	0.37	0.62	0.72	0.77	0.82	0.84	0.84
% Mn	15						
ρ_{green}	2.88	4.67	5.30	5.69	5.98	6.14	6.40
ρ_{rel} real	0.36	0.60	0.68	0.73	0.77	0.79	0.82
ρ_{rel} mod	0.37	0.63	0.72	0.76	0.80	0.83	0.82

Theoretical density was calculated and the values are shown in Table 5.

Table. 5. Theoretical density of samples

% Mn	5	7	9	11	13	15
$\rho_{theoretic}$	7.82	7.81	7.80	7.78	7.77	7.76

Compressibility curve are presented in Figure 3 using values from Table 4.

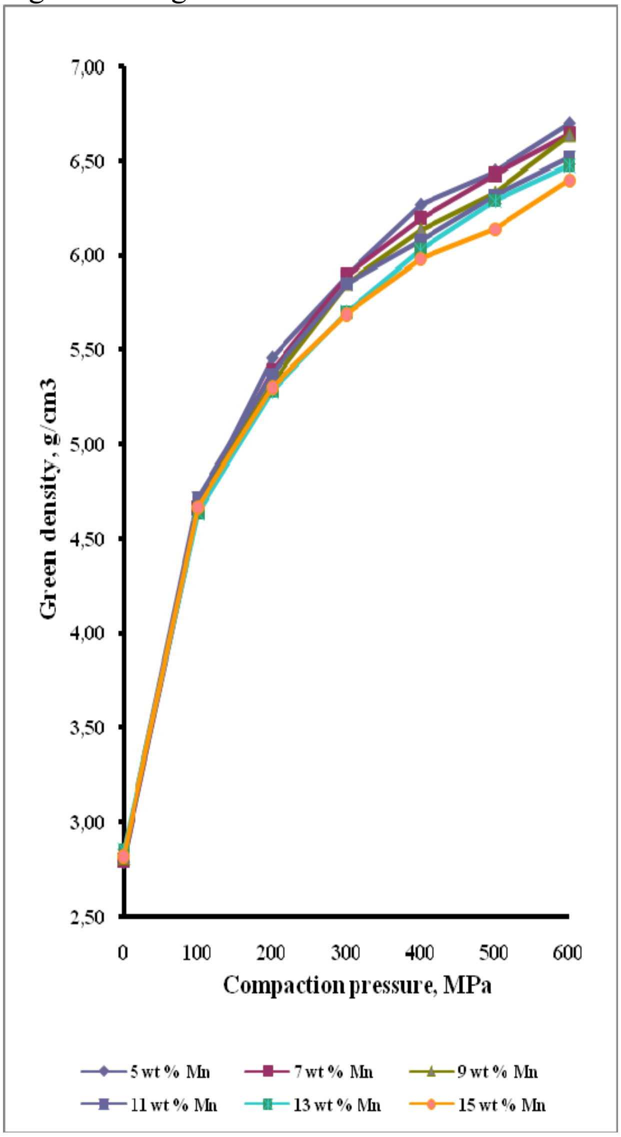

Fig.2. The compressibility curves for the mixed iron and ferromanganese powders.

From Figure 2 results that the additions of manganese (ferromanganese) in iron powder determine a decrease of green density [3].

The negative influence of ferromanganese in iron powder is because of his lower plasticity and higher hardness [4]. Powders with 5 wt. % Mn exhibited the best compressibility. At 600 MPa compacting pressure, the specimen with 5 wt. % Mn have 6.69 g/cm^3 density.

Verification of the values it was made by a numerical analysis. It was made a simulation of relative density of powders using Marc AutoForge software. It was made simulation for powders with 5, 7, 9, 11, 13, 15 wt. % Mn. The obtained values for relative density are in the Table 4.

The relative densities calculated and simulated of mixed powders versus compaction pressure are presented in Figures 3-8.

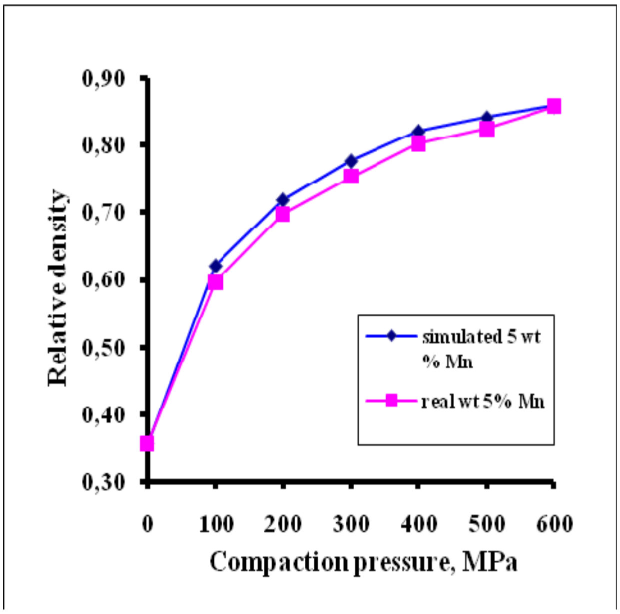

Fig. 3. Real and simulated relative density curves of samples with 5 wt. % Mn.

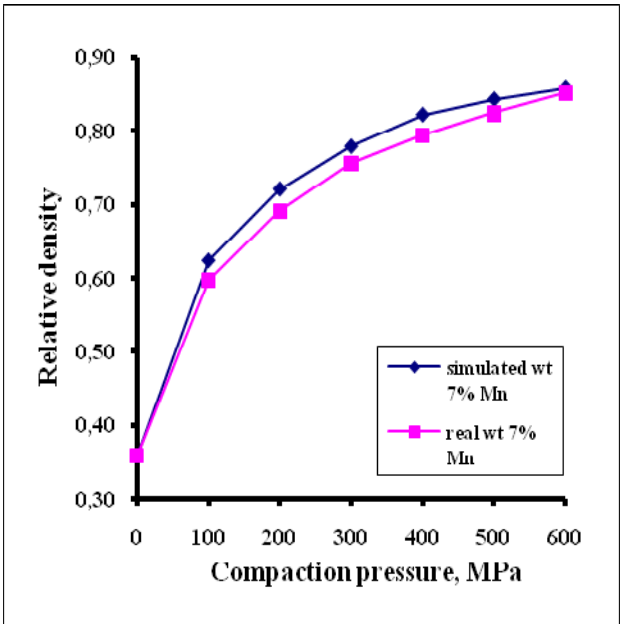

Fig. 4. Real and simulated relative density curves of samples with 7 wt. % Mn.

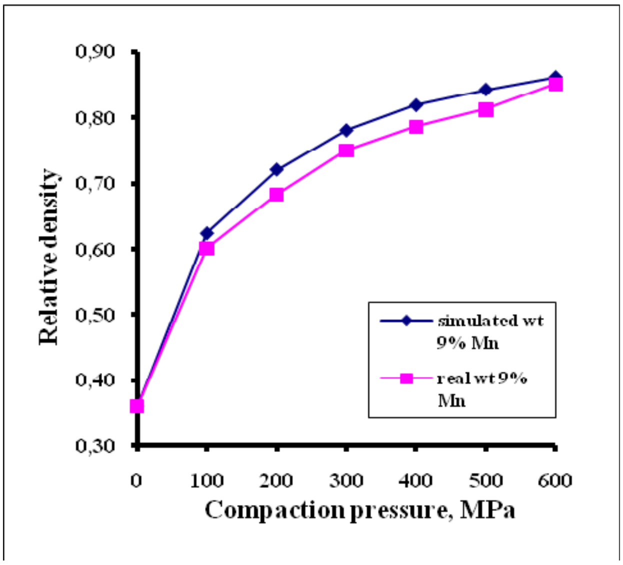

Fig. 5. Real and simulated relative density curves of samples with 9 wt. % Mn.

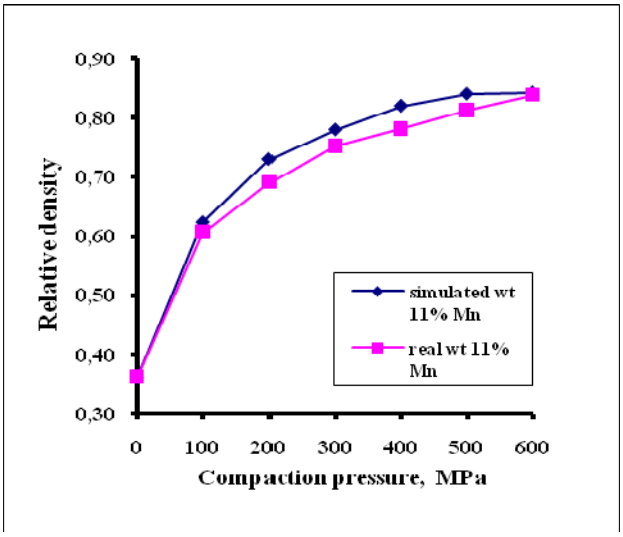

Fig. 6. Real and simulated relative density curves of samples with 11 wt. % Mn.

In Figure 3-8 it was observed that real and simulated curve initially for 100 MPa and 200 MPa increases sharply and after that it is slowly increased for pressure range 300-600 MPa.

The values of relative density start at 0.36 and arrive to 0.82-0.86 depending on the manganese content in all cases.

From the figures 3-8 it can be seen as the start and the end values of real and simulated density are identical.

Real density is lower than simulated density for all contents of manganese.

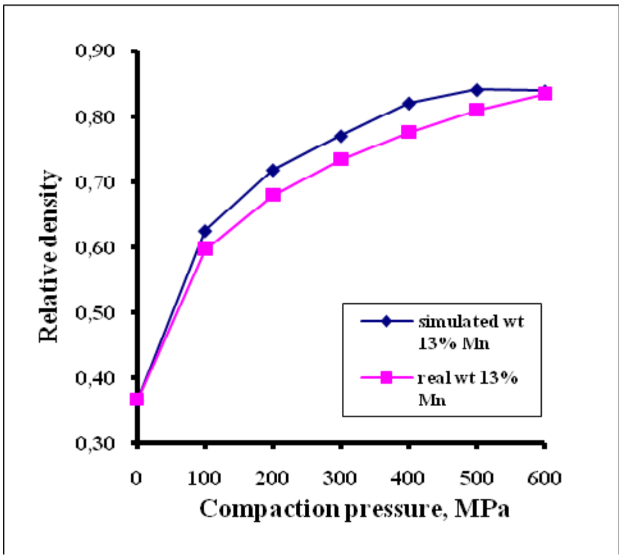

Fig. 7. Real and simulated relative density curves of samples with 13 wt. % Mn.

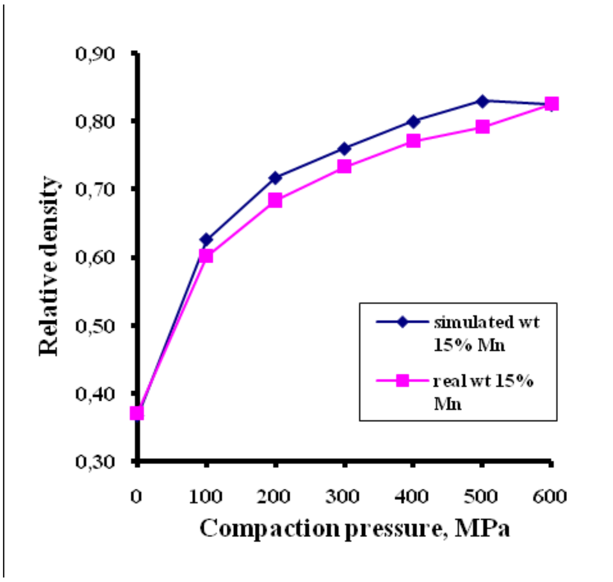

Fig. 8. Real and simulated relative density curves of samples with 15 wt. % Mn.

In Figures 3-8 it was recorded a difference between real density curve and simulated density curve because the measurements for real curve are made outside the die and the samples were relaxed. For the simulated curve the values of relative density was calculated from software inside of die.

To better appreciate the values of density it was made on Marc AutoForge software a map of relative density distribution of specimen with lower content of manganese.

The specimen with 5 wt. % Mn presents the highest values of green density

We can observe, the higher density (yellow area) is induced around the top circumference of the sample and lower density at the middle (blue area), Figure 9, as in [5].

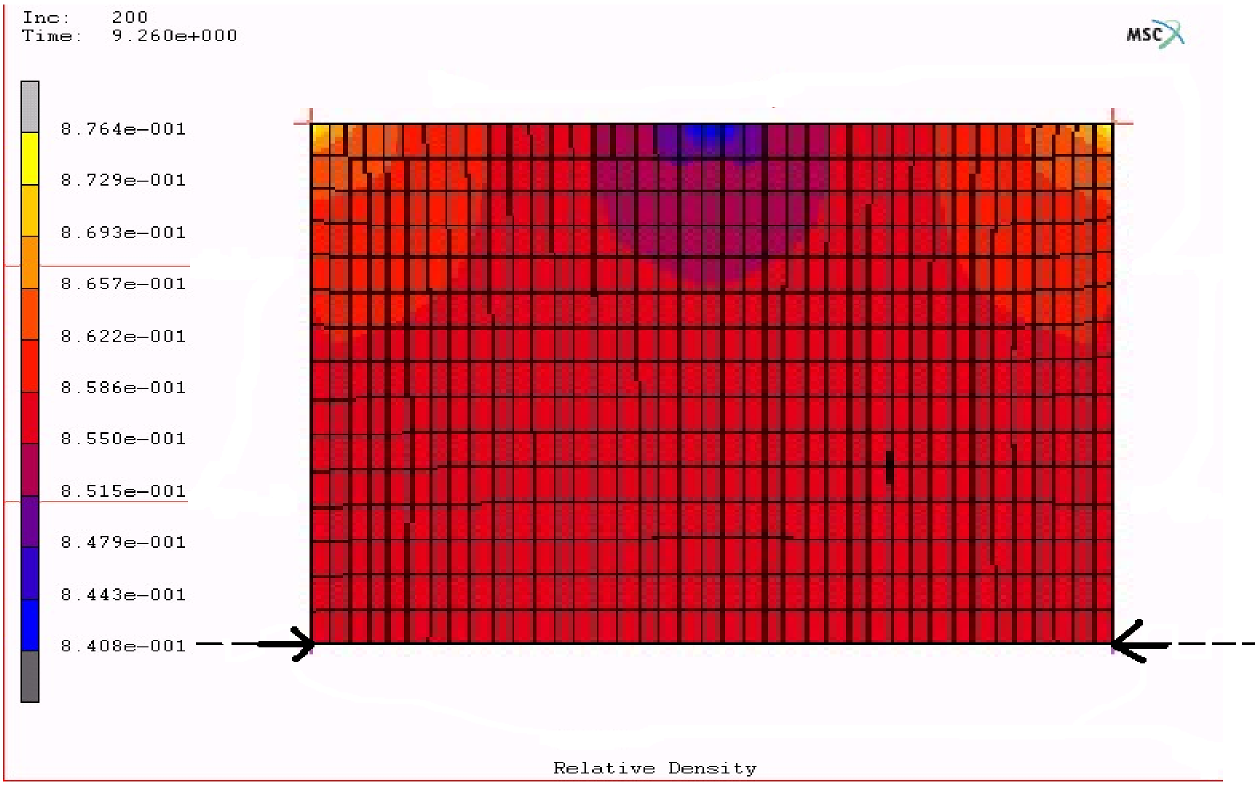

Fig. 9. Relative density distribution in longitudinal section of specimen with 5 wt. % Mn. The arrows show the force application.

This phenomenon can by explain by friction between die walls and powder and within the powder itself and result a non-uniform density on the sample.

The low density near bottom of the compact explains the widespread use of double action compaction.

The relative density differences (and the implicit variations in stresses and contact geometries) are the main reason why compacts, upon sintering, do not shrink uniformly [6].

4. CONCLUSIONS

The study outlined the following:

- The green density is influenced by compacting pressure and Mn content;
- Compressibility decreases as manganese content increases.
- The powder with 5 wt. % Mn presents the best compressibility;
- Simulation of relative density of powders using Marc Autoforge software shows the same values for relative density like calculated series.
- The higher density is induced around the top circumference and lower density at the middle of the sample.

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Modelarea densitatii presatelor din amestecuri de pulberi de fier si feromangan

Rezumat: *S-a efectuat un studiu experimental asupra densitatii amestecurilor din pulberi de fier si feromangan. S-a investigat influenta adaugării de mangan in procente de pana la 15 % in pulberea de Fe asupra compresibilitatii. S-au preparat probe cilindrice din amestecuri de pulbere de fier (DWP 400) si pulbere de feromangan (FeMn80C20). Probele au fost bilateral presate la 100 pana la 600 MPa. Probele presate au fost analizate prin masurartori de densitate dar si prin metdoda numerica. Densitatea amestecurilor de pulberi scade cu cresterea continutul de mangan, si are o valoare maxima la un continut de 5% Mn.*

Cuvinte cheie: *densitate, mangan, fier, simulare.*

Cristian SUCIU, Drd. Ing., Universitatea Tehnică din Cluj – Napoca, Facultatea de Ingineria Materialelor şi a Mediului.

George Arghir, Prof. Dr. Fiz. Ing., Universitatea Tehnică din Cluj – Napoca, Facultatea de Ingineria Materialelor şi a Mediului.

Ioan PETEAN, Dr. Ing., Universitatea Tehnică din Cluj – Napoca, Facultatea de Ingineria Materialelor şi a Mediului.

Dan FRUNZA, Conf. Dr. Ing., Universitatea Tehnică din Cluj – Napoca, Facultatea de Ingineria Materialelor şi a Mediului.

Liviu BRANDUSAN, Prof. Dr. Ing., Universitatea Tehnică din Cluj – Napoca, Facultatea de Ingineria Materialelor şi a Mediului.