INFORMATION ABOUT THE ENGINEERING OF SUSTAINABLE AND DURABLE MATERIALS (E.S.D.M)

Avram NICOLAE[1][2], Mirela Gabriela SOHACIU [3*], Ioana CSÁKI [3], Sorin CIUCĂ [4], Maria NICOLAE [5], Ruxandra Elena DUMITRESCU [6]

A new scientific branch is defined and characterized, i.e. the Engineering of Sustainable and Durable Materials (E.S.D.M), studying a new generation of materials, called sustainable and durable materials (S.D.M.). They are designed, manufactured and used on the basis of sustainable and durable technologies (S.D.T.), which: maximize the resistance of materials to degradation and maintain to acceptable values the sustainment capacity and resilience of the natural-ecological system.

In this paper, we present the principles substantiating the S.D.T.

Also, we present the objectives to be solved in the future for the development of E.S.D.M.

Keywords: materials, eco material, support capabilities, system resilience, degradation.

1. Introduction

The human sphere, as mega system, consists of four systems [1]:

The technological system (T.S.), which requires the manufacture and use of high-performance materials;

The natural-ecological system (N.E.S.), which requires the manufacture of eco-materials;

[1] Prof, Faculty of Materials Science and Engineering, University POLITEHNICA of Bucharest, Romania, avramnicolae73@yahoo.com

[2] Prof, Faculty of Materials Science and Engineering, University POLITEHNICA of Bucharest, Romania, *corresponding author: mirela.sohaciu@upb.ro

[3] Prof, Faculty of Materials Science and Engineering, University POLITEHNICA of Bucharest, Romania, ioana.apostolescu@upb.ro

[4] Assoc. Prof., Faculty of Materials Science and Engineering, University POLITEHNICA of Bucharest, Romania, sorin.ciuca@upb.ro

[5] Prof, Faculty of Materials Science and Engineering, University POLITEHNICA of Bucharest, Romania, nicolae_maria@yahoo.com

[6] Assoc. Prof., Faculty of Materials Science and Engineering, University POLITEHNICA of Bucharest, Romania, ruxandraelenadumitrescu@gmail.com

The social system (S.S.), which requires the manufacture of socio-materials;

The economic system (E.S.), which requires the manufacture of economically efficient materials.

The investigation of these systems is currently carried out by applying the principles of two modern concepts:

The concept of sustainable and durable development (S.D.D.);

The concept of global knowledge (G.K.) [6].

As targets for study, the social system and the economic system are of secondary importance to the materials engineer, since at present the majority of materials are launched in production after the acknowledgement of their properties of socio-materials and economically efficient materials.

Mastering knowledge of the interactions and interconditioning between the technological system (T.S.) and the natural-ecological system (N.E.S.) has now become an objective of major concern for the materials engineer. This objective is the essence of the research methodologically designed and conducted based on a new paradigm, called *ecological-technological (eco-technological) paradigm* [2, 5].

The eco-technological paradigm grants to N.E.S. the primary role in the development of events in the human sphere, because it provides the required conditions for optimizing the activities in the other systems. Because of this, it is called *foundation system*. The other systems, including T.S., are called *parasitic systems*.

The *T.S.-N.E.S.* complex consists of three areas (Figure 1):

a) The technological system area (T.S.)

It is the area where the **performance material** is manufactured under advanced processing conditions ensuring the function of *technological performance* imposed by the restrictions in the field of use.

It's about *technological performance*, because it shows that:

- The material was manufactured based on the *latest technical standards*;
- The *technological transfer of the knowledge* acquired through scientific research has been carried out.

If this material is the result of a chain of successive processing, it can also be considered an *advanced material*.

b) The interaction and interconditioning area located upstream of T.S. (T.S. upstream A)

In this area, N.E.S. fulfills its fundamental role as natural resources provider for T.S.

The N.E.S. potential to provide (sustain) natural resources is a *function* called **sustainability**. It is assessed through the *sustaining capacity (support capabilities)*.

c) The interaction and interconditioning area located downstream of T.S. (T.S. downstream A)

It is the area where N.E.S. is subjected to *high-intensity shock strains*. It is currently considered that most important shock strain is the pollution caused by storing polluted residues in N.E.S.

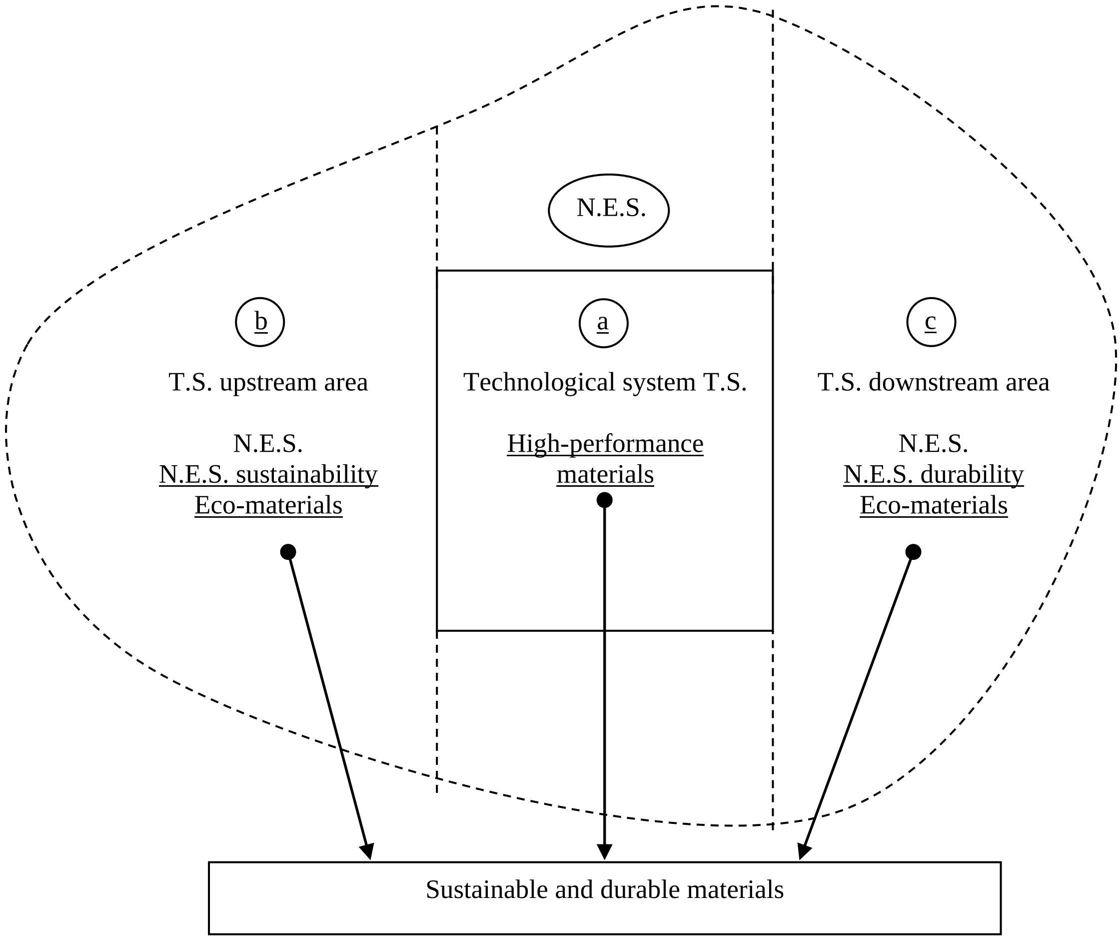

Fig.1. Eco-technological diagram of the T.S. – N.E.S.

The N.E.S. potential to not suffer imbalances due to these strains is a function called **durability**, assessed through the ecological system resilience.

The material that does not greatly harm the sustainability and durability of N.E.S. is called **eco-material**.

The **materials degradation** is a fundamental process that negatively influences the interactions and interconditioning in the convergence areas between T.S. and N.E.S, because [3, 4]:

– In *b* area, the consumption of natural resources is increased due to the premature removal of materials from use;
– In *c* area, the amount of pollutant residues generated by degradation increases.

The materials degradation occurs throughout the life cycle (*l.c.*) of the material, and not only in the use phase. For this reason, the ***resistance to degradation*** is a complex property which was not satisfactory defined to date.

The multifunctional material that simultaneously fulfills the functions of performance material and eco-material is **the sustainable and durable material** [7].

2. Materials and methods

The **materials** used in this research were documentary and informative materials supporting the shift from *specialized knowledge* focused on a single system (*horse goggle* knowledge) to *global knowledge*, designed on several systems (*fanwise* knowledge).

We used the following **methods**:

- Interdisciplinary investigation ;
- Eco-technological paradigm.

3. Results and discussions

3.1. Brief characterization of the materials engineering

The engineering of sustainable and durable materials (E.S.D.M) is the field of knowledge that studies the methodologies, strategies and techniques for optimizing by maximization the performance of materials by maintaining the sustainability and durability of the natural-ecological system at acceptable levels.

The E.S.D.M. characterisation for the iron and steel manufacturing industry (steel) will be made according to the technological flow in figure 2.

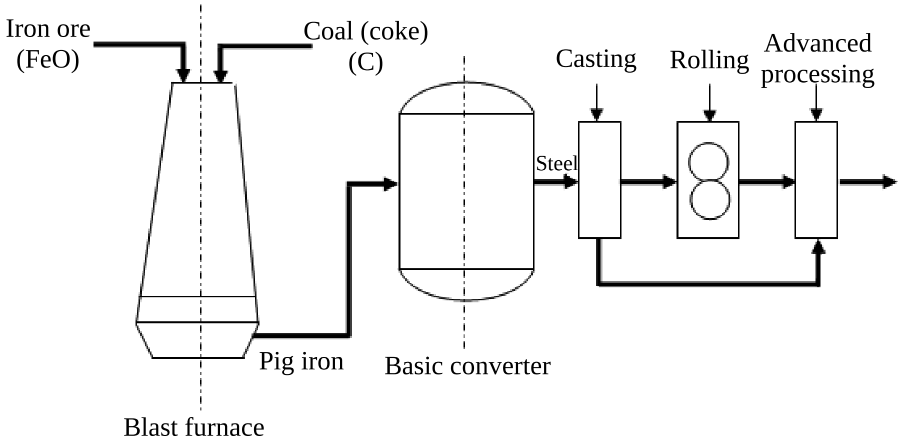

Fig.2. Technological flow (⟶) in iron and steel-making industry

The basic principles of E.S.D.M. are:

- Supporting the N.E.S. sustainment capacity;
- Maximizing the resistance to degradation;
- Supporting the N.E.S. ecological system resilience;
- Expanding the specific technologies with positive effect on N.E.S., of which the most important is the *re-integration (recovery) of waste by using the 3R technologies (recovery, recirculation, regeneration)*.

3.2. Sustainable and durable technologies

The sustainable and durable technologies are the engineering rules for operationalization of the manufacturing and use processes of the sustainable and durable materials.

Here are some recommended technologies, broken down per life cycle phases:

a) The design phase of the material

The ***materials designing engineer*** must fully know the life cycle of the material and have skills and abilities related to:

- *Predictive activity* on some events with possible negative effects on the functions of the sustainable and durable material;
- *Anticipating* modalities, methods and solutions for pre-interpreting the above events.

b) The preparation phase of resources

The ***technological matching*** of the resource properties with the subsequent properties of the material is the basis of resource preparation.

c) The manufacturing phase

The ***purity of steels*** is an important target to be pursued and met. In this context, the *Non-Metallic Inclusion Engineering* is the scientific sub-field based on which we can obtain *programmed inclusions*, leading to high resistance to degradation.

Minimizing the resource consumption and *minimizing the amount of manufacturing waste* are also certain technological programmes of great importance.

d) The use phase

The use technologies must *minimize the interactions* between the material and the destructive environment factors (technological or environmental), which generate *use waste and residues*.

e) The reintegration (recovery) phase, by applying the 3R technologies (recirculation, recycling, regeneration) [8, 9]

The materials engineer must turn the waste into materials able to be reintegrated.

* From the technological point of view, the material able to be reintegrated is the material which, after the waste recovery processes, acquires similar properties to those of the manufactured material;
* From the environmental point of view, the material able to be reintegrated is the material which:
  - By waste recovery it reduces the amount of waste that would otherwise be converted into pollutant residues;
  - It converts waste into substitutes for the natural resources;
    * From the information point of view, the waste carries information on the causes leading to material degradation.

f) The phase for environmental engineering services

It is the phase for ecological storage of the polluting waste generated in the previous phases of material life cycle.

3.3. Eco-technological confusions occurred in the manufacture and use of S.D.M.

a) Friendly environment is a wrong expression**.** The technological system, producer of degradable materials, must be always friendly.

b) Emissions zero or **zero pollution** are expressions that do not reflect the reality.

b.1.) Comment from the thermodynamics point of view.

As thermodynamic system, the T.S. is represented in Figure 3.

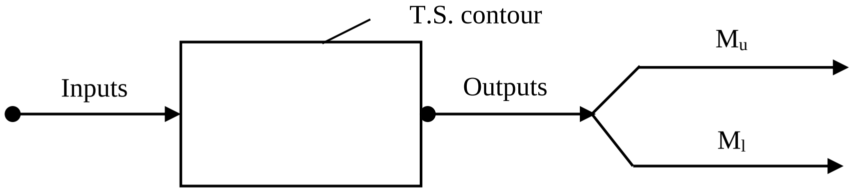

Fig.3. Thermodynamic pre-presentation of the T.S.:
M_u – useful parameters; M_l – lost parameters.

The lost parameters, M_l, are pollutant residues (M_{pol}) stored in the environment.

$$M_l \equiv M_{pol}$$

According to the first principle of thermodynamics, it cannot be a system with $M_l = 0$, and therefore neither a system with $M_{pol} = 0$.

b.2.) Comments in terms of systems theory

As an informational system, N.E.S. can be represented as shown in Figure 4.

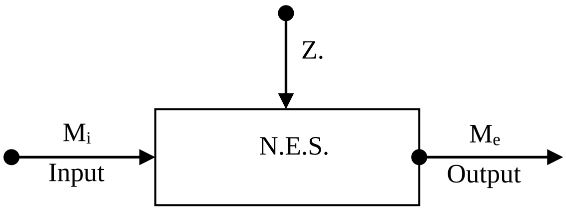

Fig.4. Representation of N.E.S. (Z – Disturbance variables)

It is currently considered that, for N.E.S., the most important disturbance variables (Z) are the pollution parameters, P_{pol}, represented by the residues stored in the environment.

$$P_{pol} \cong Z$$

The systems theory states that, in order to be functional, a system must be attacked by a minimum dose of Z, which introduces new information that M_i do not have.

Note:

- ✓ To be in ecological balance, N.E.S. must have a minimum dose of Z, i.e. a minimum dose of pollutants [10].
- ✓ Not only that zero pollution (emission) cannot exist [first law of thermodynamics], but for ecological balance, a minimum dose of pollution in N.E.S. must exist (systems theory) [11, 12].

- ✓ It is recommended to use the expression minimization of pollution (emission).

b.3.) Comments in terms of technology

The elaboration of cast iron and steel, according to the flow presented in figure 2, is based on the processes:

$$(FeO)_{ore} + (C)_{coke} \Leftrightarrow Fe + \underset{\uparrow \atop CO_2}{CO}$$

$$(FeO)_{ore} + CO \Leftrightarrow Fe + CO_2$$

In order to make cast iron and steel, the direction of the above reactions must be permanently maintained to the right. This means that the production of ferrous materials is a process that generates CO_2 *objectively and mandatory*.

b.4.) Comment from the economical point of view

We have given up this type of flow to prevent the formation of CO_2, which means giving up 65% of world steel production.

b.5.) Comment from the energy consumption point of view

Unlike France (more than 90% of the electricity is obtained in atomic power plants) or Norway (over 90% of the electricity is produced in hydroelectric power plants), most countries (Germany, Romania and others) obtain 55% of the electricity in thermal power plants operating with fuels, i.e. with CO_2 emission. Warning them to abandon in short-term the emissions of CO_2 means to ask them to stop using electricity.

c) The electric arc furnaces (E.A.F.) operating with scrap do not pollute the environment with CO_2 is an incomplete formulation. In the general case of electrical equipment, the principle that must be applied is *"I act locally, but I have to think globally"*. Acting locally, they do not produce CO_2, but thinking globally, it is found that the electricity consumed by them is supplied from a coal-fired power plant generating CO_2.

d) The waste is suffocating us is a wrong expression. Because waste is a by-product recovered by applying the 3R technologies, it does not interact with the environment. The residues are the ones stored in nature and able to pollute the environment. So, the correct expression is ***"the residues are suffocating us***".

e) The green energy, expression used to characterize the solar, wind, hydro and geothermal energy, is not fully realistic. For example, in the case of wind energy, the installation used to recover this energy is made of materials produced upstream by a polluting plant. Therefore, in this case it is also acted locally, but not thought globally.

f) The regenerable energy is also a wrong expression to characterize the solar, wind, hydro or geothermal energy. According to the second principle of thermodynamics (the principle of entropy) the energy that leaves a production or use contour turns irremediably into degraded energy dissipated in the environment as unusable entropy.

It is recommended that, instead of green energy or regenerable energy, to use for the wind, solar, hydro or geothermal energy the names unconventional energy, renewable energy or unlimited energy.

4. Conclusions

- ✓ The sustainable and durable materials engineering is a new scientific branch which, by widening the knowledge horizon, recommends studying a *new generation of materials*, called *sustainable and durable materials* (S.D.M.).
- ✓ Characterized as *multifunctional* material, S.D.M. is the result of *sustainable and durable technologies*, which:
  - Maximizes the material resistance to degradation;
  - Maintains the sustainment capacity and ecological system resilience of N.E.S. at acceptable values.
- ✓ It should be noted that notions such as: *resistance to degradation, sustainment capacity of N.E.S., ecological system resilience of N.E.S. and information potential of waste* are not currently known satisfactorily.

R E F E R E N C E S

[1]. *Berbecaru A., Predescu A., Coman G., Pantelimon C., Drăgan C., Grădinaru C., Predescu C., Nicolae A.,* Ramuri ştiinţifice de dezvoltare durabilo-sustenabilă în metalurgie, Ed.Printech, Bucureşti, 2018;

[2]. *Nicolae A., Nicolae M., Berbecaru A., Predescu A., Coman G.,* Dezvoltare durabilo-sustenabilă în industria materialelor metalice, Ed. Printech, Bucureşti, 2015;

[3]. *Nicolae, A., Predescu C., Berbecaru A., Munteanu E., Giurconiu C., Coman C.,* The importance of the material degradation properties for characterization of the waste generation processes, Meta. Int., nr.2, p.118, 2013;

[4]. *Predescu A. M., ş.a.,* Elemente de ingineria degradării materialelor, Ed. Printech, Bucureşti, 2019;

[5]. *Nicolae A., Drăgan C.I., Grădinaru C., Rucai V., Nicolae M.,* Ecotechnologyes – a major route for durable-sustainable development in the metal materials industry, The Annals of "Dunărea de Jos", Univ. Galaţi, fasc.IX, (Met. and mat. sciens), nr.1, p.27., 2016;

[6]. *Nicolae A.,* The sustainable codevelopment requires shifting from the „goggle wise" knowledge to „from wise" knowledge, Acta Technica Napocensis, Series EE DDE, nr.3, p.17-32., 2014;

[7]. *Nicolae A., Predescu C., Nicolae M.,* Materiale durabile (materiale sustenabile), Ed. Printech, Bucureşti, 2016;

[8]. *Sohaciu M.G.,* Tehnologii de reintegrare a deşeurilor industriale, Ed. Printech, Bucureşti,

2016;
[9]. *Ciocan A.*, Valorificarea deşeurilor metalice, G.U.P., Galaţi, 2008;
[10]. *Nicolae A., Sohaciu M., Nicolae M.,* Obsolescence of metal materials and products, IOP Conf. Series: Materials Science and Engineering, Vol.572, doi:10.1088/1757-899X/572/1/012075, 2019;
[11]. *Rusănescu C.O., Rusănescu M., Anghelina Fl. V.*, Variation of mechanical properties with temperature for an ecomaterial; Optoelectronics and advanced materials – rapid communications, Vol. 7, No. 11-12, p. 947-951, 2013;
[12]. *Sohaciu M., Grădinaru C., Grecu A., Duma R., Nicolae A.*, The ecological essence of the metallic materials degradation processes; U.P.B. Sci.Bull., Series B, Vol.82, Iss. 2, p.237-243, 2020;
[13]. *Rusănescu C.O., Rusănescu M., Biriș S.S., Voicu Gh., Enescu M.C.,* Research on the Mechanical Characteristics of a Microalloyed Steel with V in the Agreement with Environmental Trends; REV. CHIM.(Bucharest), Vol.70, Iss. 5, p. 1774-1777, 2019.