ECO-SOCIO-TECHNOLOGICAL DEGRADATION OF THE METALLIC MATERIALS

Cătălin Ștefan GRĂDINARU[1], Mircea Cristian PANTILIMON[2], Andrei GRECU[3], Andrei Constantin BERBECARU[4], Mirela Gabriela SOHACIU[5]*, Cristian PREDESCU[6], Avram NICOLAE[7]

The scope is to research the degradation of materials in eco-socio-technological coordinates, given that this process of anti-durable and sustainable development is the result of destructive interactions occurring in the convergence areas of three systems: natural-ecological (N.E.S.), social (S.S.) and technological (T.S.). The investigations are based on state-of-the-art paradigms: global knowledge and eco-socio-technological paradigm. A new field of knowledge is defined: the engineering of materials eco-socio-technological degradation. Various types of degradation are analyzed, taking into account the technological, environmental and social restraints.

Keywords: materials degradation, durability, sustainability, socio-technological interactions

1. Introduction

The durable and sustainable development of the human existence sphere, made up of the natural-ecological system (N.E.S.), the social system (S.S.) and technological system (T.S.) depends on the influence exerted by the *disturbing control parameters* (DCP) on the interactions occurring in the zones of convergence among the above-mentioned systems. The human existence sphere has the size of a megasystem (M.S.). In the field of manufacturing and use of

[1] PhD student, Faculty of Material Science and Engineering, University POLITEHNICA of Bucharest, Romania, e-mail: catalin_grdnr@yahoo.com
[2] Lecturer, Faculty of Material Science and Engineering, University POLITEHNICA of Bucharest, Romania, e-mail: mircea.pantilimon@upb.ro
[3] PhD student, Faculty of Material Science and Engineering, University POLITEHNICA of Bucharest, Romania, e-mail: andrei.grecu931@yahoo.ro
[4] Reader, Faculty of Material Science and Engineering, University POLITEHNICA of Bucharest, Romania, e-mail: andrei_berbecaru@yahoo.com
[5] Prof., Faculty of Material Science and Engineering, University POLITEHNICA of Bucharest, Romania, *corresponding author: mirela.sohaciu@upb.ro
[6] Prof., Faculty of Material Science and Engineering, University POLITEHNICA of Bucharest, Romania, e-mail: cristian.predescu@upb.ro
[7] Prof., Faculty of Material Science and Engineering, University POLITEHNICA of Bucharest, Romania, e-mail: avramnicolae73@yahoo.com

materials, a fundamental process of disruption of optimal interactions is represented by the transformations (structural and functional changes of the systems and their components) undergone by materials during their life cycle. The above statement refers to *entropic changes* that increase the structural disorder of the substance and decrease the in-use performance by *irreversibly changing* the primary (useful) materials into secondary materials (waste and residues). Specifically, it is about altering the properties of the technologically advanced material, sociomaterial and ecomaterial [1].

Losing (reducing, spoiling) the qualities of a material is the essence of a process called degradation. [2, 3] There are many definitions for material degradation, which are almost exclusively based on *material corrosion.* [4-9]

The material degradation (M.D.) is the process by which its manufacture, use and reintegration generate secondary materials (waste and residues), with disruptive influences on the N.E.S. [10].

We also propose the form shown below.

The material degradation *is the fundamental process under which the negative affectation of its functional integrability is manifested*, or, more concretely, *the alteration of the quality characteristics of the product throughout its life cycle*.

Therefore, M.D. is an *anti- sustainable and durable development* process, explained by the following aspects:

– It negatively influences the sustainability of N.E.S., because it causes the increase of consumption of natural resources (N.R.) that have to replace the obsolete materials; in the metallic materials industry, the consumptions are actually *extensive consumptions*;

– It negatively influences the durability of N.E.S., as it increases the amount of waste and residues that can become *polluting materials* [11].

Due to the increase in N.R. and pollution, M.D. it is an *antisocial process*.

2. Materials. Paradigms

The materials used to create this paper are part of a *documentary resource* that provides required knowledge for the development of a *new field of knowledge*: *the research of the materials degradation in eco-socio-technological coordinates*. By extension, the authors consider that this field can be considered as having the magnitude of a *new scientific branch*.

The paradigms used in the research for this paper were represented by the issues mentioned below.

The *global knowledge* is, in short, characterized by:

- Creation and dissemination of knowledge on the interactions among the three fundamental systems of the human existence sphere: natural ecological system (N.E.S.), social system (S.S.) and technological system (T.S.);
- The investigations are based on specialization, disciplinarization, inter- and trans- disciplinarization;
- The metallurgical engineer must shift from *goggle wise* knowledge to *fanwise* knowledge [12].

The ***eco-socio-technological paradigm*** used in optimizing the interactions among the three systems is based on:

- systemic approach;
- contingent approach;
- ecosystem approach;
- sectoral approach;
- highlighting the importance of T.S.

3. Results of investigations

Following the investigations, a *new field of knowledge* used by the authors to substantiate a *new scientific branch*, defined below, could be characterized.

The engineering of eco-socio-technological degradation of materials (E.D.M.) *studies the anti-development role of D.M. in achieving the sustainability and durability of N.E.S. interacting with S.S. and T.S.*

The following are elements of M.D. characterization in *eco-socio-technological coordinates*.

For the materials engineer, of prime importance is the integration of degradation into the interactions of N.E.S. with the other systems. We propose the study of this assertion to be based on the scheme presented in Fig. 1.

The scheme presented in Fig. 1 shows the fundamental interactions among the three systems. In this scheme, N.E.S. was theoretically divided into two areas:

- T.S. upstream area, Z_{up} T.S.;
- T.S. downstream area, Z_{dw} T.S.

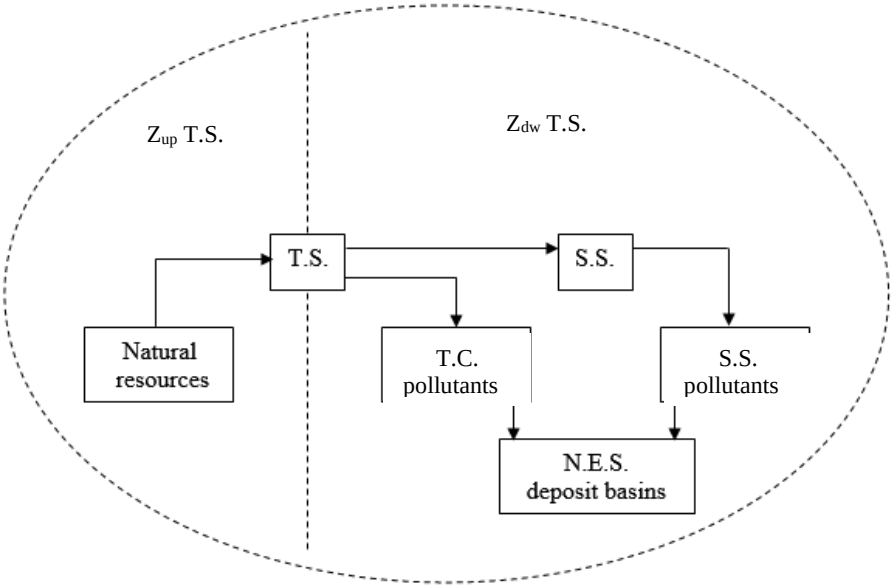


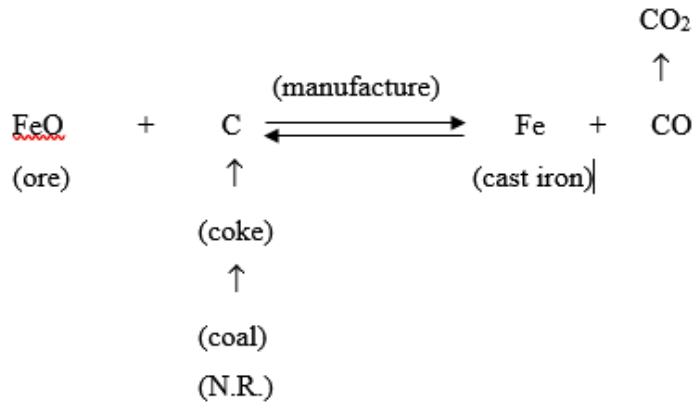
Fig.1. Scheme of the fundamental interactions N.E.S.-S.S.-T.S.

In the T.S. upstream area, Z_{up} T.S., predominant is the supply with natural resources of T.S., assessed by the specific consumption of resources, $q_{n.r.}$ [$kg_{n.r.}/kg_{mat.}$] sau by $Q_{n.r.} = P \cdot q_{n.r.}$ [$kg_{n.r.}$/year], where P is the production provided by the T.S. [$kg_{mat.}$/year];

In the T.S. downstream area, $Z_{dw.}$ T.S., predominant is the N.E.S. function of the waste deposit basin, assessed by the specific quantity of residues, $q_{res.}$ [$kg_{res.}/kg_{mat.}$], or by $Q_{res.} = P \cdot q_{res.}$ [$kg_{res.}$/year].

In the first case, N.E.S. must provide the natural resources (N.S.) required by T.S. The disruptive control parameter is the *extensive consumption of natural resources*[8], recommended by the technological rigors. Thus, when making cast iron, the coal consumption cannot be lowered below the limit imposed by the chemical equilibrium of the process:

[8] Not to be confused with *excessive consumption*, due to subjective causes.



(1)

The material degradation, revealed by decommissioning, implies an increase in the consumption of natural resources. We found the following correlations:

$$q_{N.R.} = f(q_{d.m.}) \equiv f(q_{s.m.}) \tag{2}$$

where $q_{N.R.}$ is the specific consumption of natural resources [$t_{N.R.}/t_{mat}$], $g_{d.m.}$ is the specific amount of degraded materials [$t_{mat.d.}/t_{mat}$], and $q_{s.m.}$ is the specific amount of secondary materials (waste and residues) [$t_{s.m.}/t_{mat}$].

In the second case, N.E.S. must perform the function of a basin for depositing and possibly processing of the pollutants generated by T.S. and S.S. In this situation, D.C.P. is the *pollution*. The pollutants are represented by the residues deposited in the environment; the waste being reintegrated using 3R technologies (recirculation, recycling, regeneration). We propose the following relations:

$$q_{pol.} \equiv f(q_{res.}) \equiv f(q_{m.d.d.m.}) \tag{3}$$

where $q_{pol.}$ is the specific amount of pollutants [$t_{pol.}/t_{mat}$], $q_{m.d.d.m.}$ is the specific amount of degraded material deposited in the environment, and $q_{res.}$ is the specific amount of deposited residues [$t_{res.}/t_{mat}$].

It follows from the above that for the optimization of *eco-socio-technological interactions* (N.E.S.↔S.S.↔T.S.), the material degradation plays a key role. In this context, the following classification is proposed:

- *The material degradation is D.C.P. of first rank, primarily influencing the sustainability and durability of N.E.S.;*
- *The extensive consumption of natural resources and pollution are D.C.P. of second rank, being determined (influenced) by degradation (Fig. 2).*

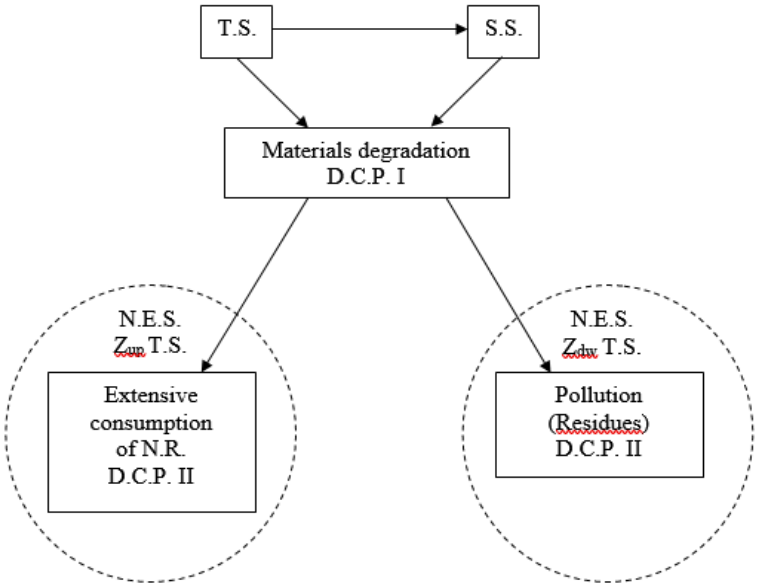


Fig.2. The role of material degradation in the eco-socio-technological interactions

The following classification is also proposed:

- *Conjunctural degradation,* which is the process with negative effects caused by subjective non-compliance (deviations) from the standards for manufacturing and use of materials;
- *Objective degradation*; in this case, we find the specific situations presented below.

a) Degradation caused by the conception (design) of the material.

The role that the design (conception) of the materials can play is part of the possible non-conformities between the design solutions and the specified requirements finally imposed to the product.

b.) Degradation caused by the manufacturing of the material (T.S.)

b.1.) The final quality of the product is clearly influenced by the quality of the processes of melting, casting and solidification of the metallic materials. The processes to be studied are:

– degradation of metal melts by impurifying with their inclusions; in this case it is necessary to know the degradation in the context of a new scientific branch: *Engineering of non-metallic inclusions* [13];

– degradation of ceramic materials used in the construction of equipment, caused by the destructive interactions between the *metal melt and the ceramic material*; it is about the ceramic materials that make up the *refractory*

lining of the installation, which is an important component of metallurgical furnaces [13-17].

b.2.) The materials processed in solid state (heat treatments, plastic deformation, etc.) can cause quality degradation by *non-conformities and process defects*.

c) Social degradation of the material.

There are two situations for the material user:

c.1.) Social degradation itself

This type of degradation is caused by the *objective deterioration* of the material during its use in the social system [18-20].

c.2.) Moral degradation of materials [21-23]

The *moral degradation of materials* is the event with technological, economic, ecological and socio-legal connotations, which consists in the *replacement* of materials and products before the decommissioning initially designed on standardized engineering bases *(premature replacement)* for objective or subjective causes, legal or illegal.

In some cases, the moral degradation is also known as *obsolescence*. [24].

Judging based on the parameters standardized by materials engineering, there are two categories of moral degradation of materials:

- unscheduled (unplanned) moral degradation, which in turn has two variants:
  - moral degradation depending on the user's (consumer's) living standard and the equipment performance;
  - moral degradation depending on disturbing issues in the materials manufacturing systems;
- scheduled (planned) moral degradation, with two variants:
  - manufacturing scheduled moral degradation;
  - use scheduled moral degradation;

d) Environmental degradation of materials.

The environmental degradation is the objective process of altering the quality of the material exposed in the environment caused by the destructive interactions occurred at the contact with the aggressive agents of the three main environmental factors: air (atmosphere), water, soil [3, 25-26]

e) Reintegration degradation of materials.

It is the process of negative modification of the compatibility between the properties of the materials obtained by processing based on 3R technologies (recirculation, recycling & regeneration) and those of the useful material to be manufactured [27-32].

In general, the above issues aim the areas of degradation integration into the phases of the life cycle. (Fig. 3)

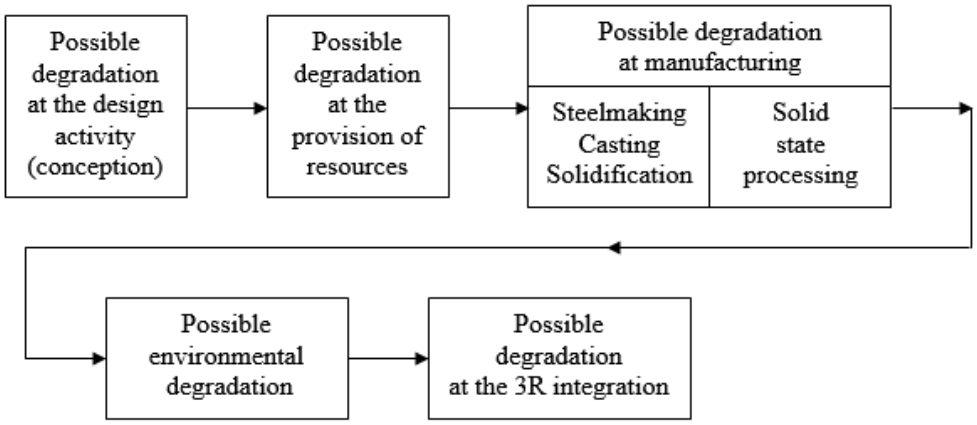


Fig.3. Degradation integrating into the life cycle phases

Fig. 3 also demonstrates that the study of material degradation as a research integrated into a multitude of processes is one of the most complex and difficult concern for the materials engineer.....

The research of degradation in eco-socio-technological coordinates operates as an *element integrated into a unitary and coherent whole*, for three fields:

- The *technological degradation* (dependent on T.S.), a field that aims at the qualitative alteration of materials in the manufacturing phase of the life cycle;
- The *social degradation* (dependent on S.S.), a field that aims to worsening the living standard by degradation; in this case, a specific situation must be also investigated, i.e. *the moral degradation of materials*, which in some particular cases is known as *obsolescence*;
- The *environmental degradation* (dependent on N.E.S.), which refers to two situations:
  - Qualitative depreciation of the materials attacked by some destructive components of the environmental factors, but also

Qualitative depreciation of environmental factors caused by the deposits of degraded polluting materials.

4. Conclusions

The durable and sustainable development of the natural-ecological system (N.E.S.), which interacts with the social system (S.S.) and the technological system (T.S.), is influenced by two fundamental phenomena occurring during the manufacture and use of materials: increasing structural disorder of the substance

and alteration of the use performance, due to the transformation from useful material (primary material) into secondary material (waste or residue).

The phenomena presented above are the essence of an anti-development process known as ***materials degradation***. It is the result of the eco-socio-technological interactions occurred in the areas of convergence among the three systems. The research of materials degradation in eco-socio-technological coordinates becomes mandatory, because:

- It negatively influences the consumption of natural resources required to replace the obsolete materials;
- It increases the pollution due to waste and residues;
- It negatively affects the living standard of the population.

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