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LOAD BEHAVIOR OF AN VERTICAL AXLE WIND TURBINE MODEL WITH A FOUR BLADES PERIODICALLY COUPLED AERODYNAMICALLY

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ABSTRACT

The paper is based on experiments conducted on the wind tunnel at low wind speeds (<4.5 m/s), on an experimental wind turbine model of the Savonius type with four blades and a D/H ratio of 2.6. The four blades are periodically coupled aerodynamically. The model acted a DC generator with a speed multiplier. Experiments were performed by modifying the generator electrical charge. The results confirm the validity of the concept proposed.

KEYWORDS: Savonius rotor, low wind, wind tunnel

1. Introduction

In the classic structure of VAWT, the Savonius or "S" rotor model is considered representative for this class of turbines. The main advantages of the Savonius turbines are: very simple principle of operation, constructive simplicity and independence from the wind direction [1]. The main drawbacks are their low yield (maximum 14.81%) and constructive difficulties at high wind speeds [1, 2].

A horizontal section through the turbine highlights the "S" shape (Fig. 1). For the position of the blade plane perpendicular to the wind, the highest of torque to the different resistance to the wind (Fig. 2) is obtained [1]. Differences between D_{cv} and D_{cx} resistors determine a result that produces a mechanical torque that determines the rotation. At wind speed *v* the *ω* angular velocity and the blade tip *u* are reached (Fig. 1). Other intermediate positions of the pair of blades gives different torque force values as measured by (2). There is also a dead point where the torque is zero and from which the turbine comes out due to inertia [3]. An increase in the VAWT efficiency of the Savonius type is achieved by changing the blade profile to create a slight deadweight load and then balancing faster pressures between the convex and concave areas. As a result, specific blade profiles have been developed, but the blade overlay and gap spacing have been developed (Fig. 4, Fig. 5) [4].

The power of wind depends on wind speed (v), air density (ρ) and swept area (A):

$$P = 0{,}5\rho A v^3 \qquad (1)$$

The power extracted from a wind power by a VAWT Savonius type depends by Drag force (5) is:

$$D = 0{,}5 C_D \rho (v-u)^2 A \qquad (2)$$

where u is speed of blade and P is:

$$P = Du = 0{,}5 C_D \rho v^3 (1-\frac{u}{v})^2 \frac{u}{v} A \qquad (3)$$

when:

$$\lambda = TSD = u/v \qquad (4)$$

The extracted power (3) is:

$$P = 0{,}5 C_D \rho v^3 (1-\lambda)^2 \lambda A \qquad (5)$$

And the conversion efficiency is:

$$\eta = \frac{P}{P_v} = \frac{0{,}5\rho(v-u)^2 C_D u A}{0{,}5\rho A v^3} \qquad (6)$$

$$\eta = \frac{(v-u)^2 C_D u}{v^3} \qquad (7)$$

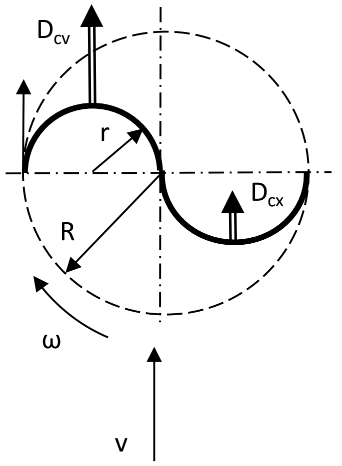


Fig. 1. *Horizontal sections trough Savonius (”S”- rotor) turbine* [1]

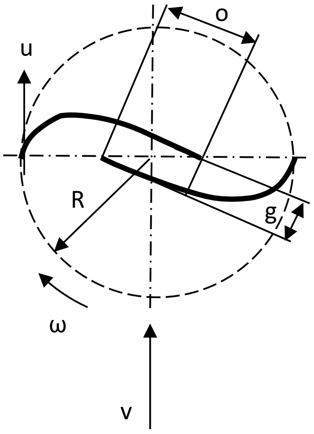


Fig. 4. *The pair of blades Benesh with gap (g) and overlay (a)* [6]

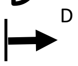
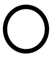
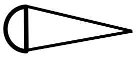
wind	profil	C_D
→		1,2
v →	 D	1
→		0,3
→		0,4
→		0,1
→		0,05
→		0,06
→		0,03

Fig. 2. *Draft force for different shape* [4]

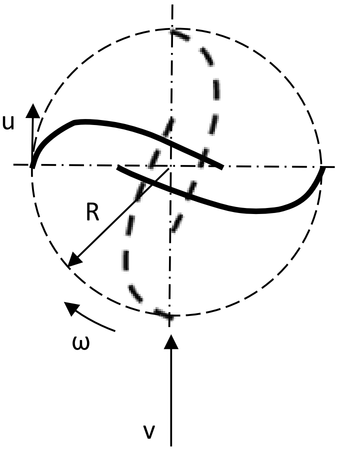


Fig. 5. *Savonius with 2 level and one pair of blades (1PB) per level in Benesh profile*

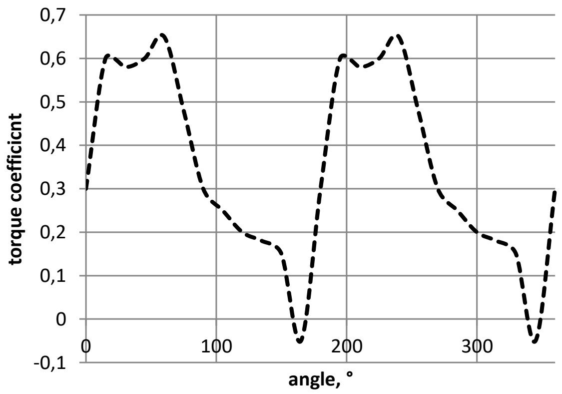


Fig. 3. *Torque coefficient variation on the axis of an "S" turbine with the rotation angle* [5]

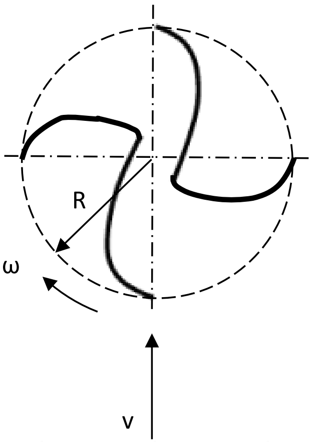


Fig. 6. *Section of the real profile of the two pair of blades (2PB) turbine*

notations:

v - wind velocity (input), m/s
u - tip blade speed, m/s
R - the radius of the disc base, m
o - overlap, m
d - width of blade, m
h - height of blade, m
ω - angular speed, radians/s
λ - specific speed
C_p *- power index*
D_{cv} *- drag force for concave surface*
D_{cx} *- drag force for convex surface*

abbreviation

VAWT - vertical axes wind turbine
TSR - tip speed ratio
PB - pair of blades
dc - direct current
Re - Reynolds number
EM - experimental model
VCC - positive potential
GND - ground potential

2. Experimental conditions and regimes

Experimental (EM) wind turbine models with a Savonius (S-rotor) vertical spindle with one and two pairs of blades (PB) and one level were developed and used as follows:

- Experimental model (EM) of VAWT type Savonius with a level and a pair of blades (1L1PB).
- Experimental model (EM) of VAWT with a level and 2 pairs of aerodynamically coupled blades (1L2PB-ac).

Experiments were conducted on an open wind tunnel with a measuring area of 0.25m^2 (0.5 m x 0.5 m) and a length of 1.25 m, and an equalization zone of 2.5 m long. Measurements were made with: LCA6000 for wind speed and an electronic rev counter for the speed of rotation of the model.

The experiments were resumed from the proposed maximum speed (4.5 m/s) to the lower wind speed limit. The mechanical and electrical load of the model has changed.

The test conditions are coded as follows:

- N - no load (mechanical or electrical);
- M - mechanical load (multiplier x 3.5 and rotor of dc generator);
- ML - idem M plus a white LED;
- ML1 - idem ML plus a 1 kΩ resistor (connected VCC to GND);
- ML1.5 - idem ML plus a 1.5 kΩ resistor (connected VCC to GND);
- ML2 - idem ML plus a 2 kΩ resistor (connected VCC to GND).

3. Results and discussions

The variation of the speed of the experimental models is shown in Fig. 7. Experimental models that have been tested at wind speeds of 0-4.5 m/s without load immediately start rotation including low wind speeds (S1L1PB, N). EM with different loads (M, ML, ML1, ML1,5 and ML2) start wind speed rotation of more than 2 m/s and the speed does not exceed 300 rpm.

TSR has a clear variation for EMs that are free (no load) and load tested (Fig. 8). Experimental models N and S1L1PB are sensitive to low wind speeds and reach λ = 0.8-1. EM with load (M, ML, ML1, ML1,5 and ML2) have a maximum for λ = 0.4-0.5 at the maximum test speed of 4.5 m/s and rotate for wind speed greater than 2 m/s.

The Re number variation is shown in Fig. 9 and Fig. 10. For TSR around 0.5 mA EM load (M, ML, ML1, ML1,5 and ML2) Re number has values before 40000-50000, being higher than in non-load tested models. The function of wind speed Re number has the same variation altitude as rotation (Fig. 7, Fig. 9).

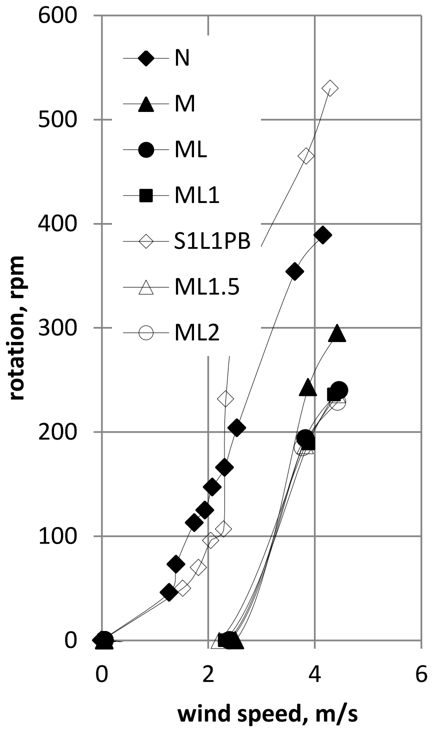


Fig. 7. *Rotation speed variation with wind speed and for different loads*

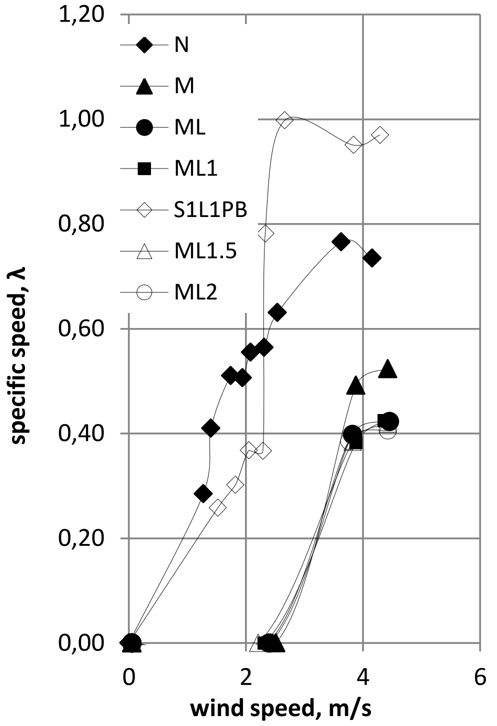


Fig. 8. *TSR (λ) with wind speed of EM for different load*

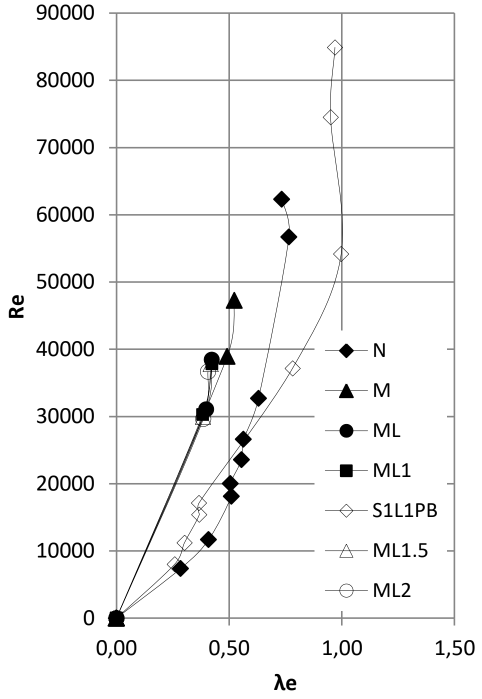


Fig. 10. *Re number variations with TSR for experiments*

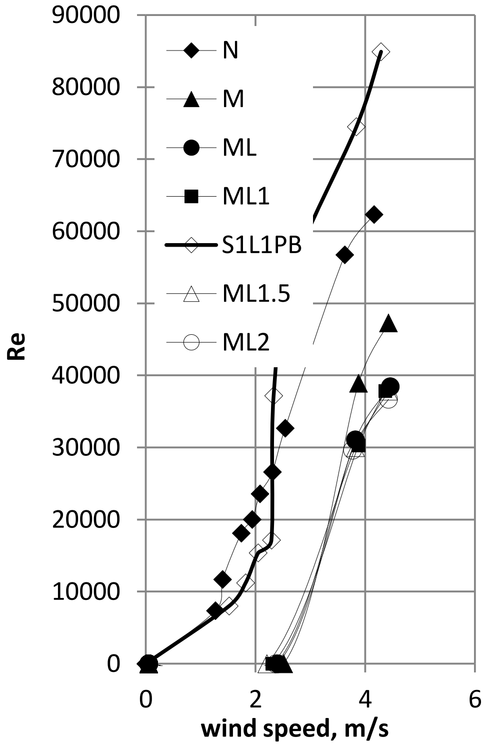


Fig. 9. *Re number variation with wind speed for different loads of EM*

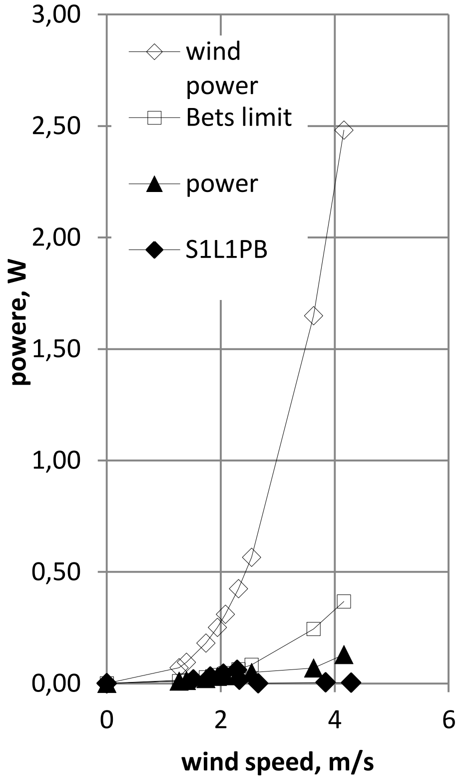


Fig. 11. *Wind power, Betz limit (VAWT) and some power extracted by EM*

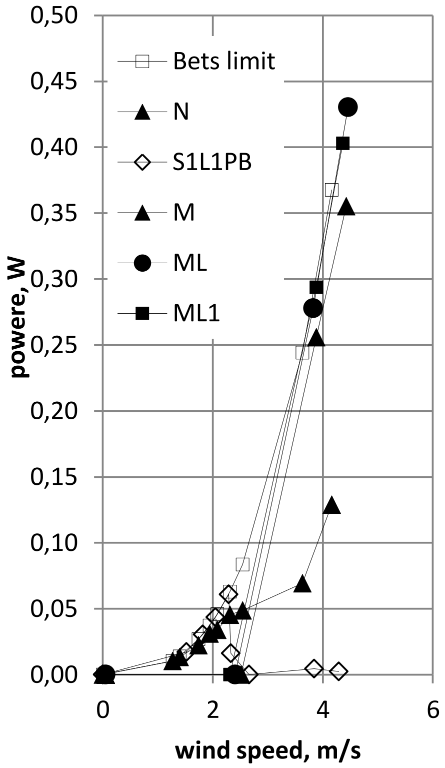


Fig. 12. Power for EM under experiments

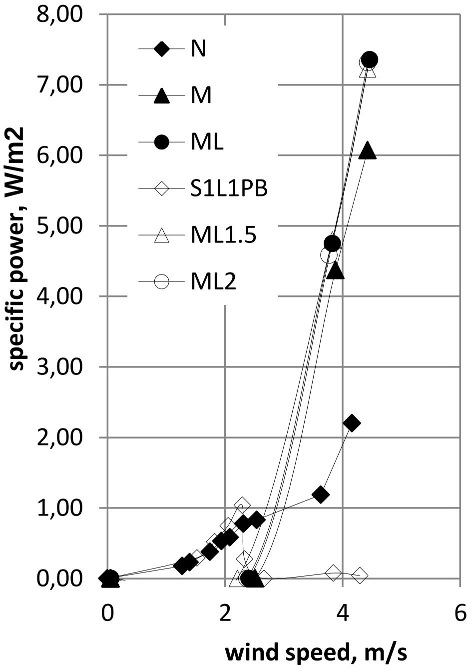


Fig. 14. Specific power with wind speed for all experiments

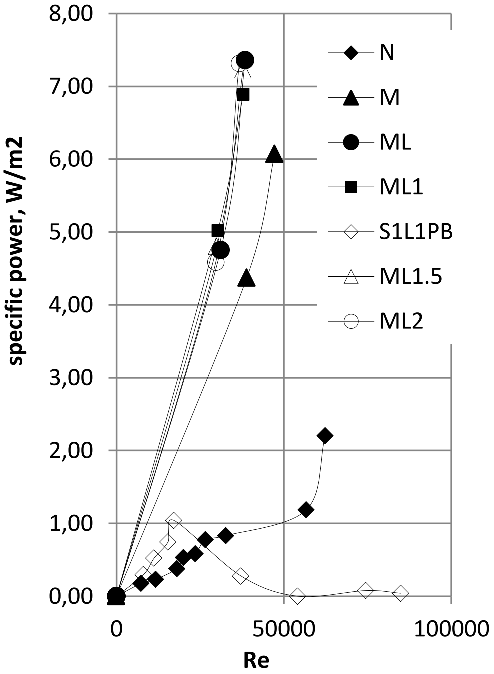


Fig. 13. Specific power for al experiments

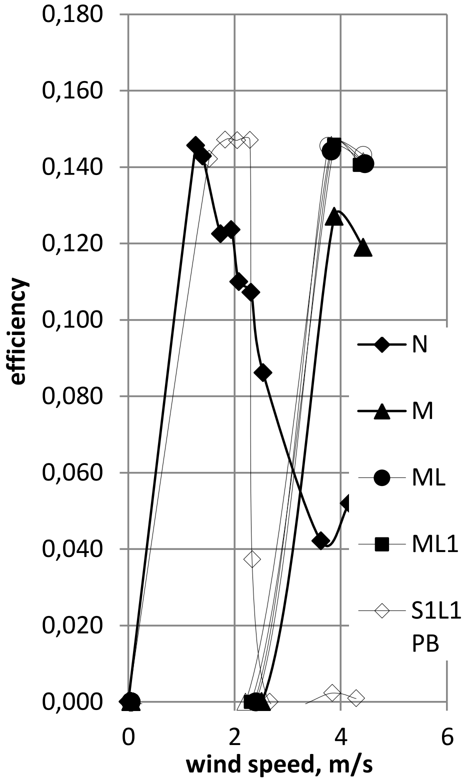


Fig. 15. Conversion efficiency with wind speed for all experiments

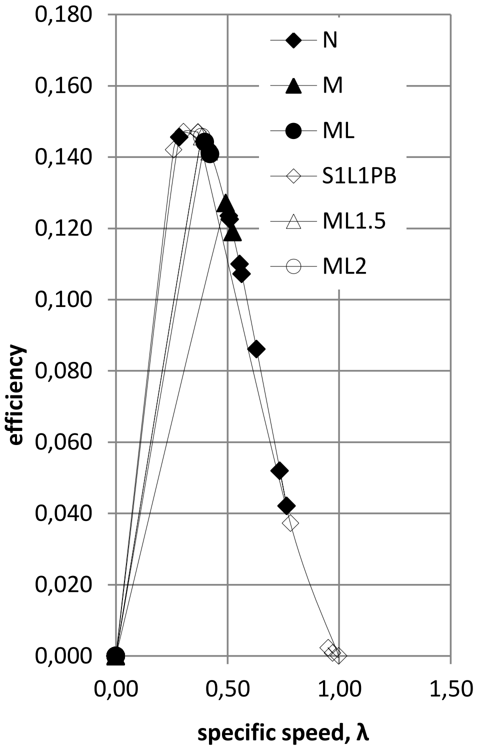


***Fig. 16.** Efficiency with TSR for all experiments*

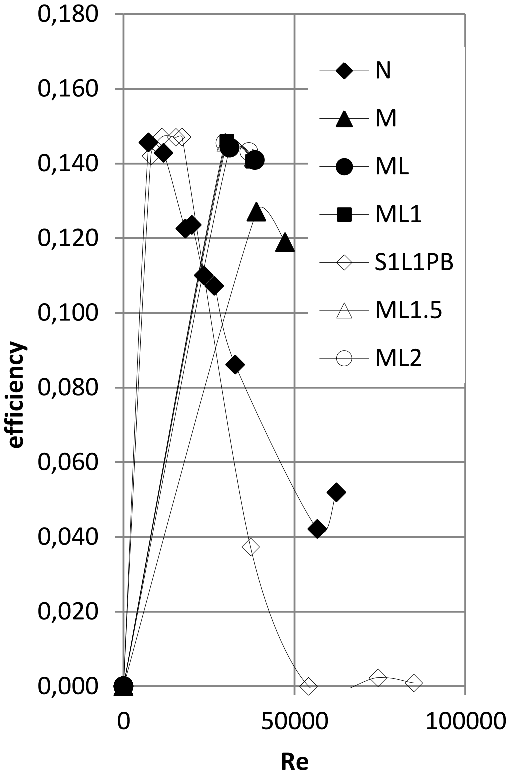


***Fig. 17.** Efficiency with Re number for all experiments*

The power extracted from the wind falls below the Betz limit for VAWT of 14.81% (Fig. 11 Wind power, Betz limit (VAWT) and some power extracted by EM). In a detailed analysis, it is noticed that the power extracted for EM under load (M, ML, ML1, ML1,5 and ML2) approaches the Betz limit and the EM tested without load (N and S1L1PB) have another variation.

Specific output power increases with Re number and for all EMs the maximum value is 7.3/m^2. For the Savonius Model with 1PB the specific power has 1 W/m^2 (no load).

4. Conclusions

The experiments followed the model of the behaviour of a vertical axis wind turbine (VAWT) with a level (1L) and two pairs of blades, as the first step in model experiments for multistage (2-5 levels).

Reference was made to a VAWT Savonius model with 1PB and one level (Fig. 1).

All models were tested in the wind tunnel under the same conditions (N, M, ML, ML1, ML1.5, ML2) from maximum wind speed (4.5 m/s) at the speed at which the model did not turn.

The items to be explored were: wind speed and wind turbine rotation. There were calculated the specific rate λ (TSR) Re number, the specific power, the power extracted, and the conversion efficiency.

For the range of wind speeds used (4.5-0 m/s), the rotation of the experimental models depends on the type of experimental model used and the load on the model. With rising load, the speed decreases (Fig. 7).

TSR (λ) and Re numbers follow this dependence mathematically (Fig. 8 and Fig. 9).

The power extracted from the experimental models with load approaches the Betz limit (Fig. 12).

Different behaviours of the experimental models loaded versus those that freely rotate shown by the specific power variation with Renumber (Fig. 13).

Regarding conversion efficiency, it approaches the Betz limit (Fig. 15, Fig. 16, Fig. 17). Experimental models tested without load achieve maximum efficiency at low wind speeds of 1.5-2 m/s. The experimental models loaded have the maximum conversion efficiency at 4 m/s.

Conversion efficiency for TSR values of less than 1 indicates that the experimental models have suffered from airflow quality, with a below approaching of 1 being desirable at least for non-load models.

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OXINITROCARBURIZING IN FLUIDIZED BED TECHNOLOGY APPLIED TO DRAWING STEELS

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ABSTRACT

Steels oxinitrocarburizing is a thermochemical treatment in order to obtain a slight increase of mechanical properties associated with increased of corrosion resistance. The paper is based on experiments performed on a plant with fluidized bed. Environment for oxinitrocarburizing is achieved by means of fluidized solid granules sorted by size ranging within 0.10-0.16 mm, resulting from decomposing a gas mixture of methane and ammoniac (initially). Samples are used in low carbon steels. Controlled oxidation is performed at a temperature of 570 °C with superheated water vapor. The results confirm the possibility to obtain layer structure and to increase surface mechanical properties.

KEYWORDS: fluidized bed, oxinitrocarburizing, drawing steel

1. Introduction

Oxinitrocarburizing (ONC) treatment is a relatively new, dedicated parts being obtained by cold plastic deformation of steel or other materials. Oxinitrocarburizing is a thermochemical treatment of low carbon steels and from which we obtain an increase in surface properties and corrosion resistance. The principle of treatment is close to the ferritic nitriding (FN) treatment, considered low-cost option. Treatment environment is usually gas or plasma, for which we obtain the lowest costs [1, 2].

In [3] oxinitrocarburizing (ONC) is considered a complex heat treatment with three stages (Triplex): CVD + Diffusion + oxidation.

Complex treatment of ferric nitrocarburizing (FNC) under different conditions and then followed by oxidation is shown in [4]. FNC is studied at various temperatures ranging from 630 °C to 570 °C and post-oxidation is performed at 550 °C.

A completed treatment of nitrocarburizing using plasma and gas environment C60W on steel samples at a temperature of 570 °C while maintaining a 4 hour and 8 hours is shown in [5].

Fluidized bed as a medium for oxinitrocarburizing has some features that are found in the advantages and disadvantages as a medium for heating:

- environment works only vertically from the bottom up;
- has a very high thermal conductivity at correct fluid flow;
- heat transfer coefficient has high values;
- mass transfer coefficient has high values;
- the pieces (samples) are set in the middle of the fluidized bed;
- there is a central movement upward, specify for wall descent of fluidized bed;
- there is an active area immediately after the fluidisation plaque (grille);
- assets are slightly sloping surfaces;
- horizontal surfaces are considered dead.

It can be noted that the fluidized layer has limitations for the fixed bed and the pneumatic transport (Fig. 1).

The properties of the fluidized bed vary with temperature and fluidization velocity. Therefore, the establishment of the quiet fluidization field leads to the optimization of the thermal and mass transfer properties and is a prerequisite for the achievement of the established processes. Depending on the speed of fluidization, the following areas are established:

- 0 ... W_{cr}, fixed bed;
- W_{cr} ... W'_f, beginning of fluidization;
- W'_f ... W''_f, the field of fluidization;
- W''_f ... W_{pl}, field of turbulent fluidization;
- $W > W_{pl}$, pneumatic transport.

Due to operating principles can be inferred that using fluidized bed can be opportune for thermal and thermochemical treatments. Altering the chemical composition of the nitriding gas: carburizing, nitriding, hardening, nitrocarburizing can be obtained.

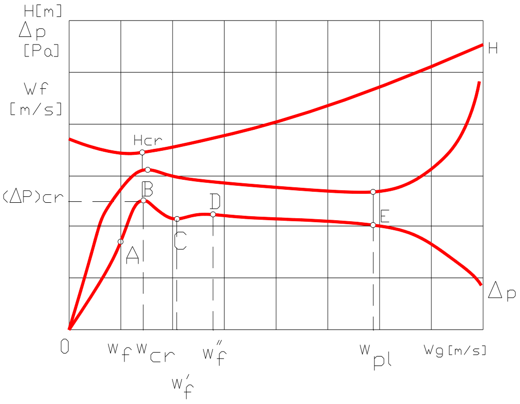

Fig. 1. *Dependency of height (H), speed of filtration and fluidization (w_f), and drop pressure (Δ_p), of gas velocity (w_g)* [6-8]

Notation and abbreviations:

w_f - fluidization speed, m/s
Δ_p - drop pressure, mbar
CVD - Chemical Vapour Deposition
ONC - OxiNitroCarburizing
CN - CarboNitriding
FNC - Ferrite Nitrocarburizing
FN - Ferritic Nitriding
O - Oxidation
W_{cr} - critical fluidization speed
W'_{f0} - minimum fluidization speed
W_{pl} - floating speed
W 's - optimal fluidization speed
W_{pl} - floating speed

The use of the fluidized bed in thermal and thermo-chemical treatments also has the advantage of being able to make diverse inlet gas mixtures by controlling the pressure and flow of each component. This is because the experimental plant is open and after the fluidized bed is evacuated, the combustion gases are completely burnt. For oxinitrocarburizing experiments in fluidized bed were used mixture of different gasses - methane, ammonia and air. After reaction in the exhaust air fluidized there are methane (butane, propane) ammoniac, hydrogen, nitrogen, except that the last ones are combustible and form water vapor and CO_2.

2. Experimental

The thermochemical treatment was performed on the fluidized bed installation of Engineering Faculty of “Dunarea de Jos” University of Galati (Fig. 2).

Installation elements are: 1 - power supply system and temperature control, 2 - fluidized bed oven, 3 - rack gas supply technological, 4 - hood to evacuate fumes [9-12].

Thermochemical treatment plant usually shows a fluidized bed evaporator posted to the gas supply to prevent water vapour oxidizing atmosphere [12, 13]. In experimental superheated water, vapour atmosphere is obtained by introducing water directly into the start of fluid found at 570 °C, with a vent pipe at the fluidized bed base, a transition regime was performed to change fluidizations on hated water vapour.

The research was based on those steel sheets prepared and rolled into industrial plant. These samples were subjected to thermochemical treatments in order to apply and obtain parts with improved wear properties and oxidation related to the automotive industry. For testing were used samples of steel with chemical composition shown in Table 1 (after annealing treatment). After surface cleaning and polishing, samples were introduced into the furnace in vertical and central position so that there will be two areas covered by oxinitrocarburizing.

Table 1. *Experimental regimes (NC+O)*

Exp.	NitroCarburizing (NC)		Oxidizing (O)	
	Tempe-rature	Time	Tempe-rature	Time
u.m.	°C	min	°C	min
1	NC650°C	60	570	120
2		80		
3		100		
4		120		
5	NC650° -> 570°C	60		
6		80		
7		100		
8		120		
9	NC570°C	60		
10		80		
11		100		
12		120		
13	NC540°C	60		
14		80		
15		100		
16		120		

Oxinitrocarburizing fluidized bed is mainly located after a continuous cycle known as thermochemical treatment because the initial mixture composition change is to modify the composition of the active gas treatments.

Table 1 shows the conditions for achieving oxinitrocarburizing thermochemical treatment.

The experimental regimes are carried out in the same fluidized bed furnace in two successive stages, for which, besides the fluidization parameters, are regulated the temperature of the regime, the chemical composition of the incoming gases, the water pressure at the vaporizer inlet.

Table 2. *Chemical composition for samples*

C	Si	Mn	P	S	Al	As	Ti	V	Cu	Ni	Cr	Mo	Nb	N2	Ca	Cev	H2
0,004	0,02	0,24	0,015	0,01	0,06	0,02	0,001	0,001	0,015	0,015	0,019	0,002	0,001	0,0065	0,0001	0,089	0

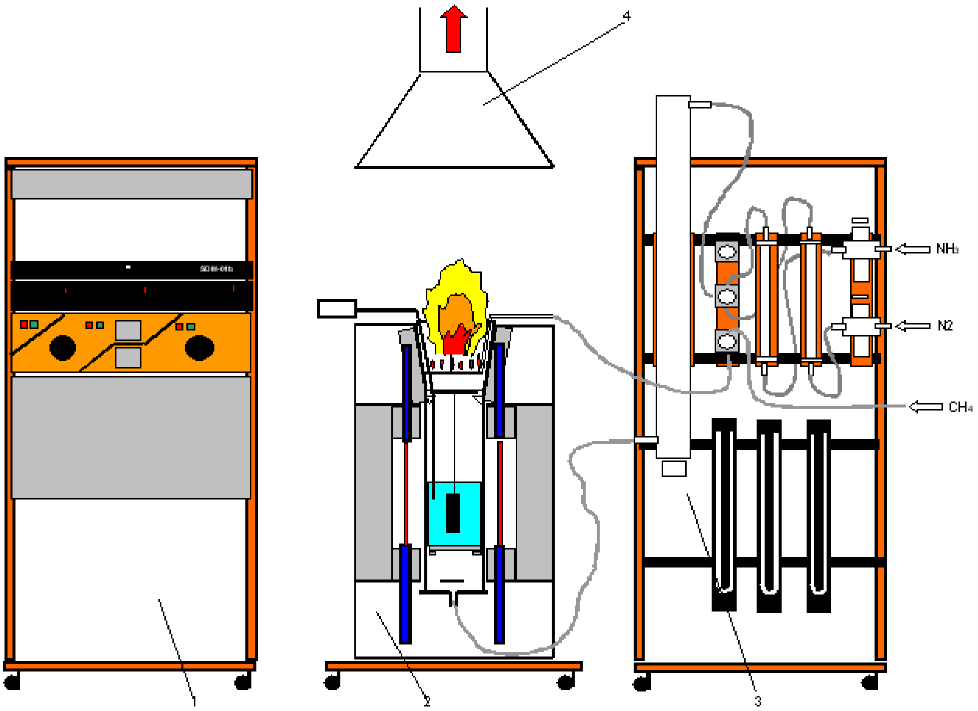

Fig. 2. *Fluidized bed laboratory heat treatment furnace: 1 - power supply system and temperature control; 2 - fluidized bed oven; 3 - rack gas supply technological; 4 - hood to evacuate fumes*

It is not necessary to remove samples from the fluidized bed; it is only necessary to avoid oxidation into the atmosphere or due to the residual moisture in the incoming gases. The oxidation was carried out at 570 °C for two hours of treatment. The duration was determined by previous tests and the temperature in the Fe-O diagram [4].

3. Results and disscutions

Investigations were conducted to determine the influence of thermochemical treatment conditions on the chemical composition, structure and properties, as follows:

- in section (layer) metallography;
- hardness over surface oxinitrocarburized layer;
- metallographic depth layer analysis.

Superficial hardness was analysed with the 5 kg hardness tester. Measurements were made on both surface hardness in each three randomly chosen points in the sections.

The paper aims at highlighting changes in the structure after application of thermochemical treatment cycle. With this respect, reference is the initial structure (blank) and the core structure of each sample.

For each sample of steel there is a clamp with nitrocarburated samples and oxinitrocarburated samples, with a minimum distance of 2 mm between samples. The clamps of the specimens are subjected to the process of preparation by grinding (abrasive stone 60, polishing with sandpaper 100, 200, 300, 500, 800, 1000, 1200) and polishing with diamond paste. Metallographic attack is made with 2% Nital. Metallographic analysis results represent the microstructure at 100x zoom for each sample.

The microstructures of the samples after NC + O complex treatment are shown in Fig. 3…Fig. 18:
The largest depth of surface layer modified after (NC + O) is for NC at 650 °C and 0.05-0.09 mm respectively. These are the layers that have the

highest hardness, the high temperature allowing an intense nitrocarburisation (NC) process.

4. Conclusions

In this paper, the behaviour of low-carbon steel samples by nitrocarburizing treatment in a fluidized bed is aimed and then followed by a water-vapour-controlled oxidation. Nitrocarburizing was carried out at 650 °C, 650 to 570 °C, 570 °C and 540 °C and oxidation at 570 °C. Basically it connects metallographic structure and hardness HV of the surface. It makes it with 5-10 loads from the core area.

As an expression of oxinitrocarburizing treatment it results in an elegant colour and surface appearance: black satin, matte. Final treatment after oxidation usually contains a space filler resulted (crevices) with a sealant (corrosion), usually oil.

In all the experimental samples there were observable alterations of the superficial layer (micrographs in section and surface hardness).

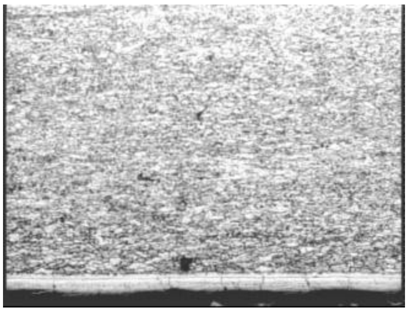

Fig. 3. *Microstructure, sample 1: (CN650 °C/60 min + O, 100x)*

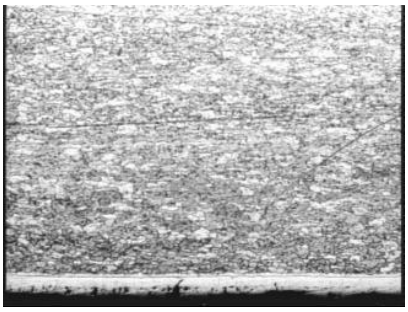

Fig. 4. *Microstructure, sample 2: (CN650 °C/80 min + O, 100x)*

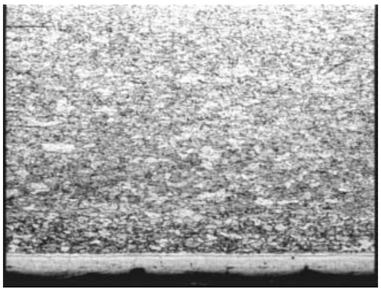

Fig. 5. *Microstructure, sample 3: (CN650 °C/100 min + O, 100x)*

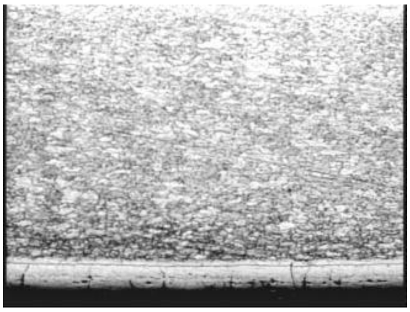

Fig. 6. *Microstructure, sample 4: (CN650 °C/120 min + O, 100x)*

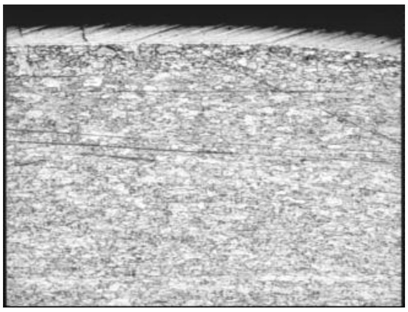

Fig. 7. *Microstructure, sample 5: (CN650->570 °C/60 min + O, 100x)*

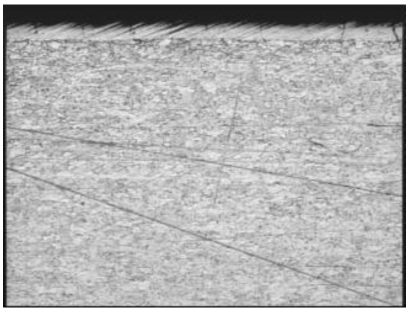

Fig. 8. *Microstructure, sample 6: (CN650->570 °C/80 min + O, 100x)*

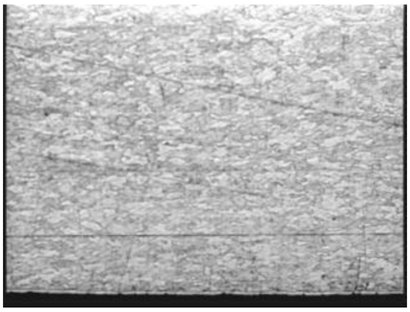

Fig. 9. *Microstructure, sample 7: (CN650->570 °C/100 min + O, 100x)*

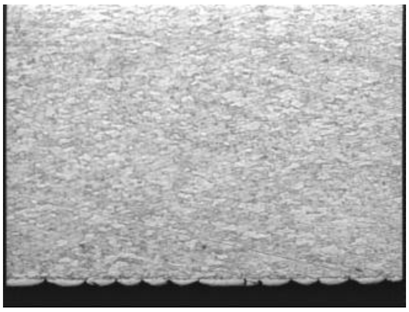

Fig. 10. *Microstructure, sample 8: (CN650->570 °C/120 min + O, 100x)*

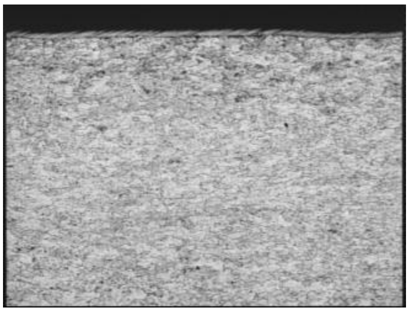

Fig. 11. *Microstructure, sample 9: (CN570 °C/60 min + O, 100x)*

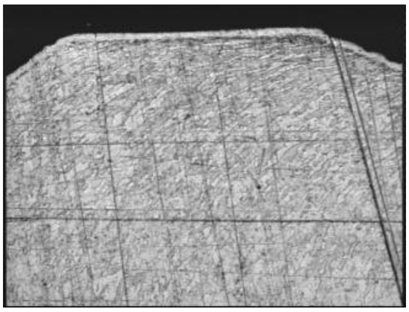

Fig. 12. *Microstructure, sample 10: (CN570 °C/80 min + O, 100x)*

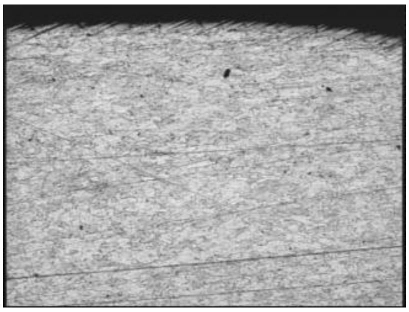

Fig. 13. *Microstructure, sample 11: (CN570 °C/100 min + O, 100x)*

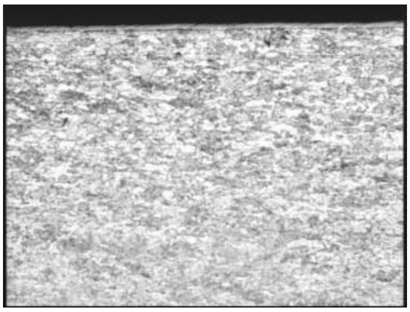

Fig. 14. *Microstructure, sample 12: (CN570 °C/120 min + O, 100x)*

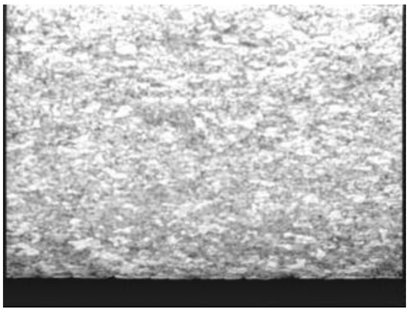

Fig. 15. *Microstructure, sample 13: (CN540 °C/60 min + O, 100x)*

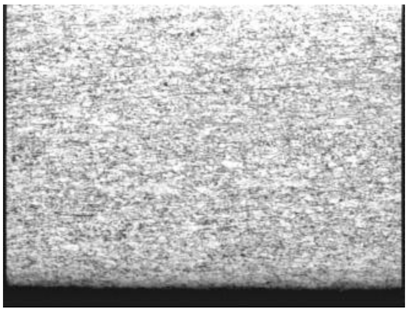

Fig. 16. *Microstructure, sample 14: (CN540 °C/80 min + O, 100x)*

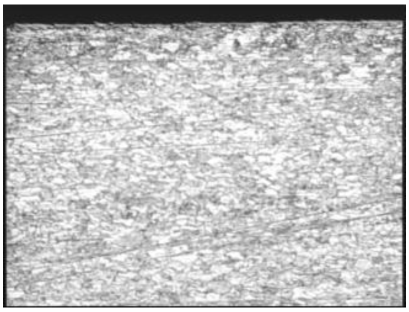

Fig. 17. *Microstructure, sample 15: (CN540 °C/100 min + O, 100x)*

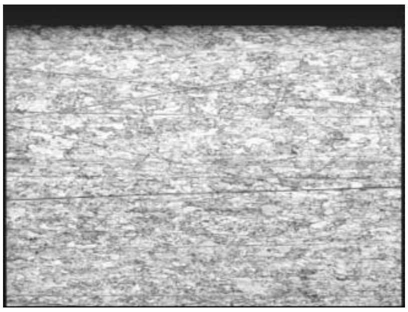

Fig. 18. *Microstructure, sample 16: (CN540 °C/120 min + O, 100x)*

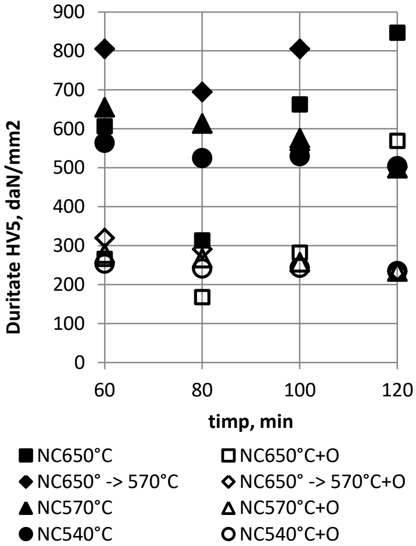

Fig. 19. *Dispersion of hardness HV5 test over all samples after CN and after CNO*

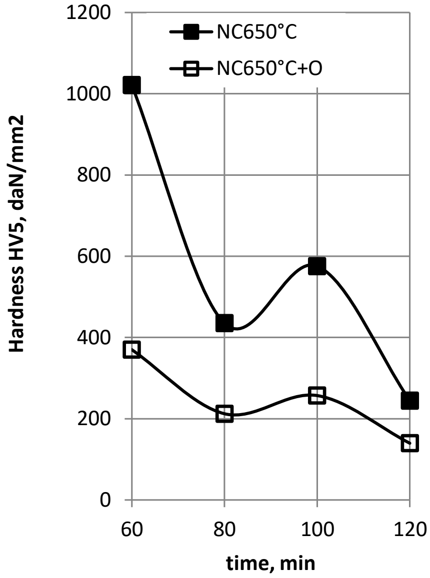

Fig. 20. *Hardness after CN at 650 °C and after O at 570 °C*

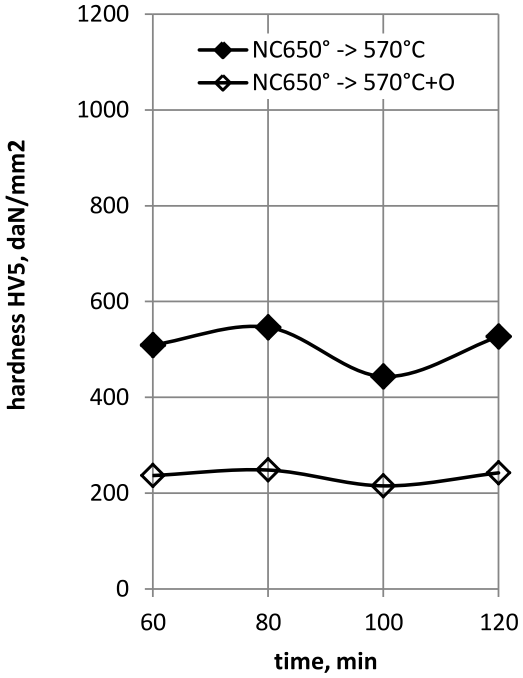

Fig. 21. *Hardness after CN at 650 °C->570 °C and after O at 570 °C*

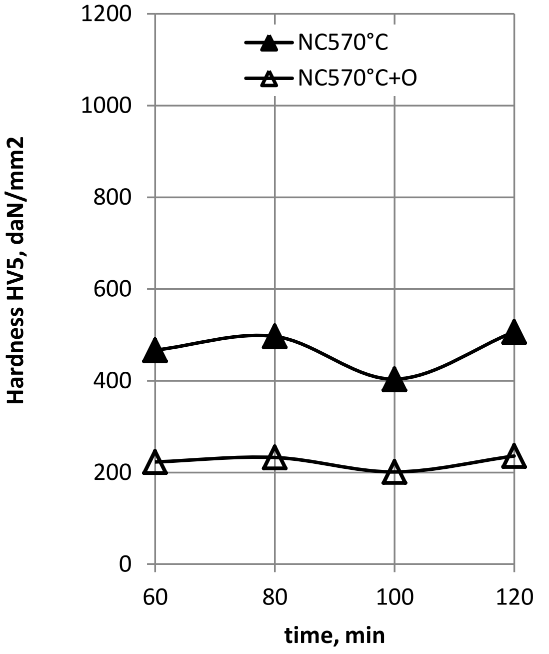

Fig. 22. Hardness after CN at 570 °C and after O at 570 °C

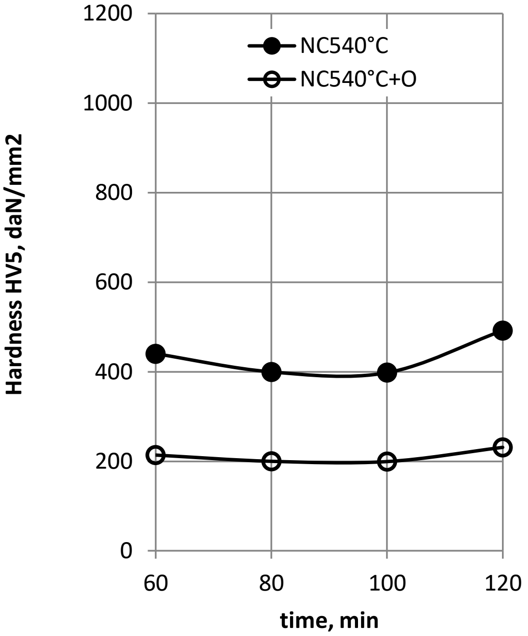

Fig. 24. Hardness after CN at 540 °C and after O at 570 °C

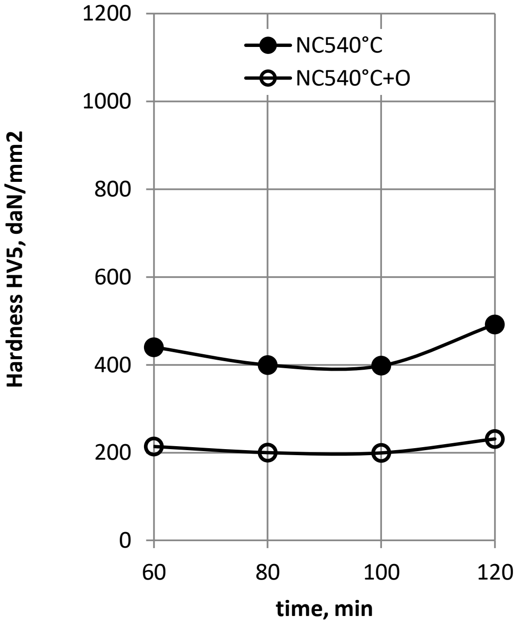

Fig. 23. Hardness after CN at 540 °C and after O at 570 °C

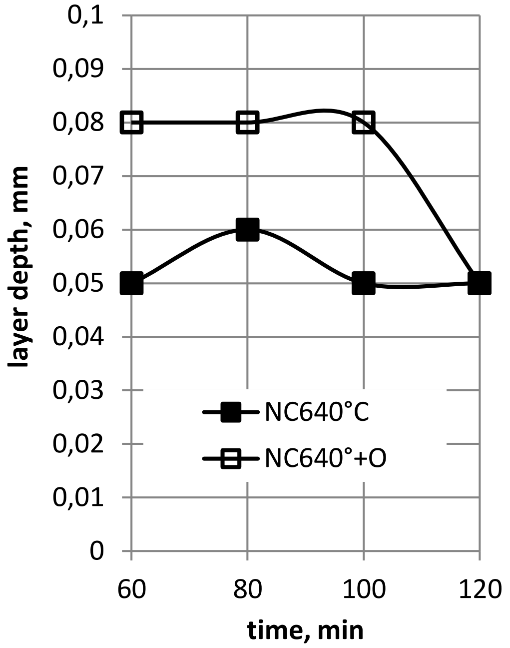

Fig. 25. Layer depth for NC at 640 °C with time and with/without O at 570 °C

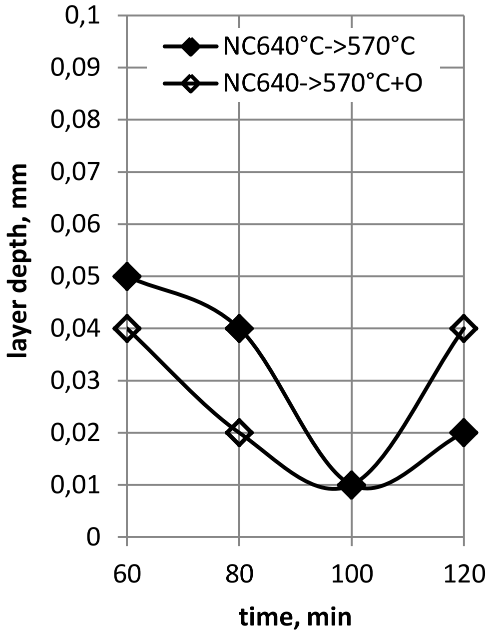

Fig. 26. *Layer depth for NC at 640 °C->570 °C with time and with/without O at 570 °C*

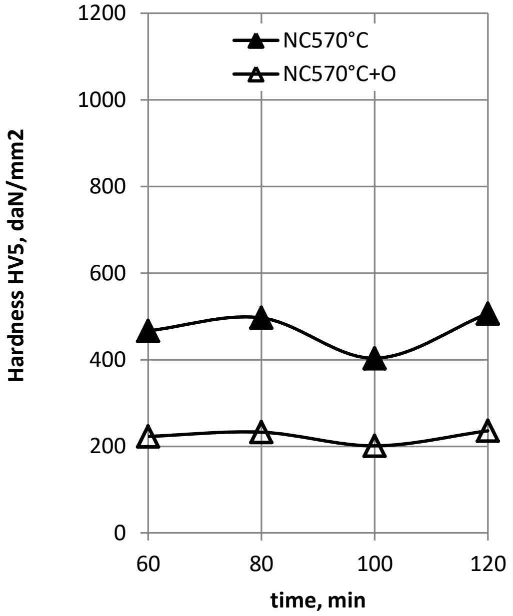

Fig. 27. *Layer depth for NC at 570 °C with time and with/without O at 570 °C*

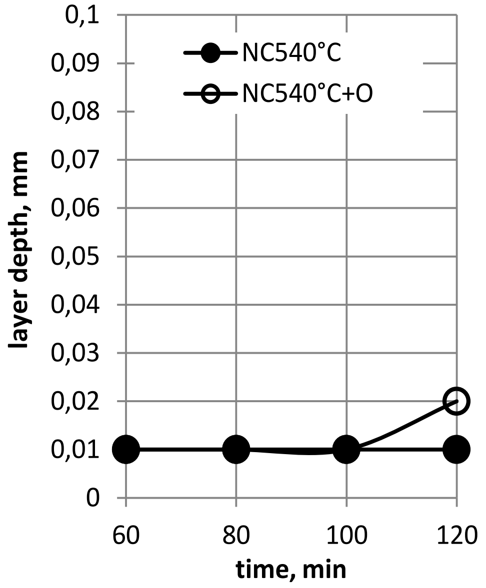

Fig. 28. *Layer depth for NC at 540 °C with time and with/without O at 570 °C*

The layer with the highest depth and the most significantly modified properties was obtained for a temperature of 640 °C, this being the highest treatment temperature (tab). By oxidizing at 570 °C, the white-specific oxidation layer increases with temperature and residence time. The hardness of the losses is higher than that of the original material (65 daN/mm^2, HV5), indicating that the layer of inert material (crushed chamfered and sorted at 0.10-0.16 mm and fluidized with methane + ammonia and air mixture, and then with over-heated water vapour, there is an active environment for NC + O processes. The lowest hardness is obtained at 540 °C being 500 daN/mm^2 (HV5) after the NC and decreasing to 250 HV (HV5) after NC + O.

The fluidized bed oxinitrocarburation process can be used to treat small parts made of stamping steels and which, after treatment, enables us to obtain better mechanical propensities and corrosion.

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STUDIES ON THE HEAT RECOVERY FROM THE SINTER COOLER, S.C. ARCELORMITTAL GALATI

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ABSTRACT

Heat recovery to the sinter plant is a means of improving the efficiency of the sintering process. The hot agglomerate must be cooled down. The heat recovered from the sinter cooler is used to preheat the combustion air for burners in the ignition furnace. In addition to heat recovery, the system helps decreases and particulate emissions, and improves sinter productivity, yield and cold resistance. This makes a recirculated type system more efficient than a non-recirculated type.

KEYWORDS: sinter, cooler, heat balance, heat recovery

1. Introduction

As is known, agglomeration is a generic term used to describe the process by which a wet blend of fine ore particles, fluxes and fuel is converted into a conglomerate. The continuous improvement of iron ore agglomeration technology as a method of pre-heat preparation of furnace ores has allowed the expansion of the raw material base for the production of iron, imparting to these aggregates a character independent from particularities of the used ores (granulometry content of harmful elements, reducibility, etc.).

At the introduction of the coagulator on the cooler, its temperature is 900-1000 °C, and at the outlet temperature drops to 80-100 °C, making it possible to carry it further on conveyors with rubber band.

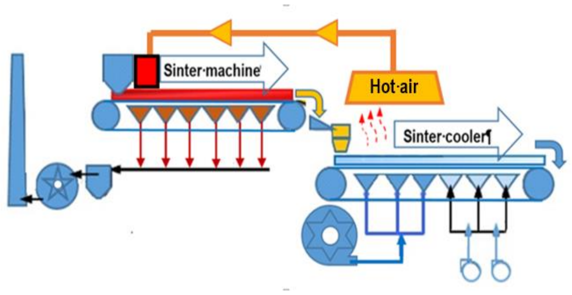

***Fig. 1.** Hot air oven*

Recovery systems: The heat recovered from the sinter cooler is used to preheat combustion air for burners in the ignition furnace and to generate high pressure steam that can be used to generate electricity. In addition to heat recovery, the system helps reduce SOx, NOx and particulate emissions and improve sinter productivity, and cold resistance (Fig. 1).

Cooling the agglomerate is done by forced air injection from the bottom up, having a significant influence on the quality of the agglomerate that is obtained. All physicochemical phenomena occurring during the sintering process are conditioned by a multitude of factors that act concurrently.

2. Objectives

Now, the heat resulting from the cooling of the agglomerate is not recovered, being exhausted in the atmosphere (Fig. 2).

***Fig. 2.** Agglomerated cooler*

The paper aims to determine, by thermal calculation of the amount of heat evacuated in the (lost) atmosphere, the graphical presentation by the Sankey diagram of the agglomeration cooler balance, as well as suggestions for using this amount of heat in order to improve the thermal efficiency of the ignition furnace of the agglomeration.

3. Theoretical considerations

During cooling, a series of stresses occur that are mechanical and can influence the agglomerate strength and granulation. These may be:

- thermoelastic (macro tension) that depends on the cooling conditions and can be removed by slow cooling (σ_t);
- interphase (micro tension) which is caused by the difference in the coefficients of thermal expansion of the phases that make up the agglomerate (σ_i);
- phases that are related to polymorphic transformations (σ_f).

The agglomerative resistance criterion must be in the form of:

$$R_{aglo} = \sigma_t + \sigma_i + \sigma_f \qquad (1)$$

Thermal balance calculation: Energy consumption is calculated on the basis of the thermal balance of the aggregate, which is a particular form of the principle of energy conservation. The reference items associated with the heat balance are the reference contour, the unit of time and temperature.

The reference contour (the outline) is the closed area associated with the thermal aggregate as the inputs and outputs of the thermal energy. This corresponds to the physical nature of the agglomeration cooler.

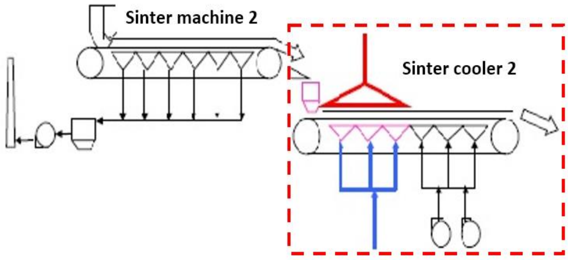

Fig. 3. Reference contour of the cooler

The reference unit (unit of time) is the time period for which the heat balance is drawn. At the agglomeration cooler the time is the operating time.

The reference temperature is the temperature at which the thermal balance components are considered. Generally, $t_0 = 0\ ^oC$ under normal conditions or $t_0 = 15\ ^oC$ under standard conditions.

The elements of the heat balance consider all the energy carriers that enter and exit the balance sheet, being expressed by the relation:

$$\sum Q_i = \sum Q_e \quad [kJ/h] \qquad (2)$$

where Q_i and Q_e represent the quantity of heat entering or leaving the balance sheet, in kJ/h.

The calculation of the heat balance on the heating cooling system allows the amount of heat generated by the cooling process, the characteristics of air-cooled cooling fans, and their dimensioning to be determined.

The quantities of heat input ($\sum Q_i$) are calculated by summing up all the quantities of heat entering the contour:

$$\sum Q_i = Q_{fai} + Q_{agi} + Q_{fci} \quad [kJ/t_{ag}] \qquad (3)$$

The physical heat of the cooling air (Q_{fai}):

$$Q_{fai} = D_a \cdot c_{ai} \cdot t_{ai} \quad [kJ/t_{ag}] \qquad (4)$$

The physical heat of the sinter cooler inlet (Q_{agi}):

$$Q_{agi} = M_{ag} \cdot c_{agi} \cdot t_{agi} \quad [kJ/t_{ag}] \qquad (5)$$

The heat of the cooler carts (Q_{fci}):

$$Q_{fci} = m_{cr} \cdot c_{ci} \cdot t_{ci} \quad [kJ/t_{ag}] \qquad (6)$$

where

- D_a is the flow rate of cooling air, in m^3N/t;
- M_{ag} - the mass of the agglomerate in t;
- m_{cr} - the mass of the carts on the cooler, kg.

The quantities of heat output ($\sum Q_e$), calculated by adding up all the heat outputs out of the contour:

$$\sum Q_e = Q_{ac} + Q_{age} + Q_{fce} \quad [kJ/t_{ag}] \qquad (7)$$

The amount of heat emitted by cooling gas (Q_{ac}):

$$Q_{ac} = D_a \cdot c_{ae} \cdot t_{ae} \quad [kJ/t_{ag}] \qquad (8)$$

The amount of heat evacuated with the sinter (Q_{age}):

$$Q_{age} = M_{ag} \cdot c_{age} \cdot t_{age} \quad [kJ/t_{ag}] \qquad (9)$$

The heat of the cooler carts (Q_{fce}):

$$Q_{fce} = m_{ce} \cdot c_{ce} \cdot t_{ce} \;\; t_{age} \quad [\text{kJ/t}_{ag}] \qquad (10)$$

where:

- D_a is the flow rate of cooling air, in m^3N/tag;
- M_{ag} - the mass of the agglomerate, in t_{ag};
- m_{ce} - the mass of the carts on the cooler, kg.

The cooling gas temperature, equalling the two amounts of heat or the heat input to the cooler, ΣQi and the amount of heat exiting the cooler ΣQe, determines the thermal equilibrium equation. This equation allows determining the amount of heat evacuated with the cooling gases, which is unknown to the balance equation. The calculation relation is:

$$\boldsymbol{Q_{ac} = Q_{fai} + Q_{agi} + Q_{fci} - Q_{age} - Q_{fce}} \qquad (11)$$

The balance table, calculating the quantities of heat entering and leaving the balance sheet when the heat evacuated with the gases is known to the atmosphere, can be taken to the drawing up of the balance sheet. It contains both incoming heat and heat out of the value balance contour expressed in kJ/h as well as the percentages of each amount of heat entering or leaving part of the heat input or output.

The balance sheet error, after the balance sheet is drawn up, shall be calculated based on the data in the table, the balance of errors made up of neglected items, errors in measurement and calculation that must not exceed 2.5%. The calculation relation is:

$$\boldsymbol{\varepsilon = (Q_i - Q_e)/Q_i} \qquad (12)$$

The graphical representation for the clearer picture of the heat inputs and out of the coil's balance sheet is the scale-based graphical representation. In this sense, a scale is chosen at which the total amount of heat entering and out of the contour will be transposed and will be represented to the left or right of the heat quantity value (Sankey diagram).

The heat economy (E) or the amount of hot air evacuated by the heat of the agglomerate when it is cooled is:

$$\boldsymbol{Q_{ec} = Q_{C\,ignition} - Q_{ac}} \qquad (13)$$

The heat recovered from the sinter cooler is used to preheat combustion air for burners in the ignition furnace [2]. The heat economy is:

$$\boldsymbol{E = {Q_{ac}}\big/{Q_{C\,ignition}} \cdot 100} \qquad (14)$$

4. Methods

Sinter cooler features. For each sintering machine there is a cooler with a useful surface of 230 m^2.

Several fans are typically used for cooling, and the cooler speed must match the demand for the grill and is determined by the speed of the grill and the bed depth. The trolleys have at the bottom a grate on which the agglomerate is laid in a layer of a maximum thickness of 800 mm, and under the cooler air is drawn through a cooling layer, resulting from 3-4 fans of the existing 8 for each cooler. Fan discharge pressure is based on the agglomerate granulometry entering the cooler and is between 200 mm col. H_2O to at least 4 fans in operation, and the total airflow is based on the amount of conglomerate on the cooler and the initial and final temperature of the cooler. This flow varies within 5000-7000 m^3/t_0.

***Table 1.** Characteristics of the F2 sinter cooler*

Surface Usable [m^2]	Height Layer [mm]	Air flow Cooling [m^3/t_s]	Speed of movement [m/min]	Agglomerated temperature [ºC]	
				entry	exit
230	800	$5 \div 7 \cdot 10^3$	2÷6	≈ 900	≈ 95

The calculation of the heat balance on the heating cooling system allows the amount of heat generated by the cooling process, the characteristics of air-cooled cooling fans, and their dimensioning to be determined.

Simplifying hypotheses. The thermal balance was based on the following assumptions:

- the layer is considered homogeneous, having an equivalent thermal conductivity and an equal initial temperature throughout the mass;
- the contact between coats placed over the cooler throughout the cooling process is perfect;
- the variation of the specific heat and thermal conductivity with temperature is considered;
- the dimensional variations (contractions) that occur during cooling are neglected;
- the inspired air flow is the same across the entire layer (loss of pressure is neglected).

***Table 2.** The balance table for the heat in*

THE HEAT IN				
No.	The heat	Eq.	Value [kJ/t_{ag}]	Percent [%]
1	Q_{fai}	3.1	433.44	0.92
2	Q_{agi}	3.2	46388.14	98.46
3	Q_{fci}	3.3	292.19	0.62
	Total (ΣQ_i)	**3**	**47113.7**	**100 [%]**

The results of sinter cooler balance. Knowing the heat balance elements allows you to determine the amounts of heat input and output form the chassis balance. Based on these, the amount of heat evacuated with the cooling air and the improvement of the thermal efficiency can be determined.

Table 3. *The balance table for the heat out*

THE HEAT OUT				
No.	The heat	Eq.	Value [kJ/t_{ag}]	Percent [%]
1	Q_{ac}	4.1	29045.58	61.65
2	Q_{age}	4.2	17903.19	38.0
3	Q_{fce}	4.3	164.92	0.35
	Total ($\sum Q_e$)	**4**	**47113.7**	**100 [%]**

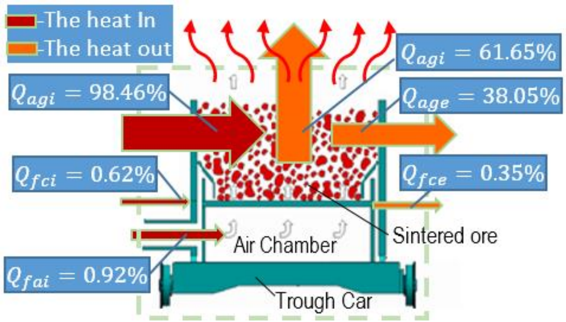

Fig. 3. *Sinter cooler thermal balance*

The heat economy (Q_{ec}) the amount of heat exhaust air, hot air Q_{ac} is:

$$Q_{ac} = \sum Q_e - Q_{age} - Q_{cre} = 29045.58 \text{ [kJ/t}_{ag}\text{]} \quad (15)$$

$$Q_{ec} = Q_{C\,ignition} - Q_{ac} = 134573.68 \text{ [kJ/t}_{ag}\text{]} \quad (16)$$

where: $Q_{Cignition}$ is the ignition furnace from the sintering machine ($Q_{Cignition}$ = 163619.271 kJ/t) [2].

The heat recovered from the sinter cooler is used to preheat combustion air for burners in the ignition furnace [2]. Percent heat savings is:

$$E = \frac{Q_{ac}}{Q_{C\,ignition}} 100 = \frac{29045.58}{163619.27} 100 = \mathbf{17.75}[\%]$$

5. Conclusions

Depending on the high exhaust gas temperature, only 30 to 40% of the cooling air of a linear cooler can be used to recover heat.

Only the final part of the sintering section and the primary part of the cooling section where the gas is at a temperature of 300 °C or higher is thus available.

By recovering the heat from the hot air from the agglomeration cooler an amount of heat can be obtained that can be used in the agitating furnace's furnace to achieve a fuel economy of E = 17.75%.

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ZnO NANOPARTICLES: GREEN SYNTHESIS, PROPERTIES AND APPLICATIONS

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ABSTRACT

In this paper, a review, there are presented “Green” routes used in the synthesis of ZnO nanoparticles because they are more eco-friendly alternatives in comparison with chemical and/or physical techniques. Microorganisms, bacteria, enzymes and plant extracts also allow a controlled synthesis and function as stabilizing or hydrolytic agents. The chemical solvents are toxic, and these methods suffer various disadvantages due to the involvement of high temperature and pressure conditions during nanoparticle synthesis.

The ZnO nanoparticles are of significant interest as they provide many practical applications in various fields: drugs, cosmetics, textile, electronic and optoelectronic, photocatalysis. The most important application of ZnO nanoparticles would be as antibacterial agents. The increased surface area and smaller size of these particles make them an ideal antibacterial agent.

In addition to the green synthesis of ZnO nanoparticles along with their antimicrobial activity the mechanism of this activity was also reviewed. The green synthesis of ZnO nanoparticles from Azadirachta indica, Aloe vera, Murraya koenigii and Anisochilus carnosus were also highlighted.

KEYWORDS: ZnO nanoparticles, green synthesis, eco-friendly, antibacterial activity

1. Introduction

A special attention was paid to the green synthesis of metallic nanoparticles using biological material as the reducing and stabilizing agents and due to the utilization of eco-friendly, non-toxic and safe reagents during the biosynthesis process [1-5]. In the green method of chemistry, not only plant extracts are used for controlled and accurate synthesis of several metallic nanoparticles [6]. High active surface due to the small size of nanoparticles are responsible for their behaviour [7, 8]. Green synthesis approaches are gaining interest preventing the high costs and usage of toxic chemicals and harsh conditions for reduction and stabilization [9]. Although, that conventional methods such as reaction of zinc with alcohol, vapor transport, hydro/solvothermal synthesis, precipitation method use less time for synthesizing nanoparticles, they contribute to environmental toxicity because they require toxic chemicals as capping agents. Therefore, the new methods for the nanoparticles synthesis are an eco-friendly alternative and it is cost effective [10-12].

Nanoparticles are synthesized owing to various and unique properties, which facilitate their exploitation in completely unrelated fields, such as, nanodiagnostics, nanomedicine and antimicrobials on one hand [13-22] and luminescence, photocatalytic potential and photodiode on the other [19, 20, 23, 24]. Zinc oxide nanoparticles (ZnO NPs) are environmentally friendly, offer easy fabrication and are non-toxic, biosafe and biocompatible, making them an ideal candidate for biological applications [25-26].

Considering this, zinc oxide nanoparticles have been successfully synthesized using biological methods [27-31].

Recently, ZnO NPs have been used in food packaging materials and various matrices and methods for incorporation of ZnO into those matrices, which have been reported. ZnO is incorporated into the packaging matrix, free to interact with the food materials offering preservatory effects [32]. Presently, ZnO NPs have found application in sunscreens, paints and coatings as they are transparent to visible light and offer high UV absorption [33] and are also being used as an ingredient in antibacterial creams, ointments and lotions, self-cleaning glass, ceramics and deodorants [34]. ZnO nanoparticles have been lately tested for their antimicrobial potential and seem to possess both antibacterial and antifungal potential. They are active against both Gram-positive and Gram-negative bacteria and show considerable activity against more resistant bacterial spores [35]. It was also observed that doping of ZnO NPs with other metals such as gold, silver, iron etc. improved the antimicrobial activity of ZnO NPs [36-37]. Also, inhibitory effects of ZnO NPs are correlated with their size and concentration, with smaller particles offering better inhibitions in higher concentrations [38-39].

2. Zinc Oxide Nanoparticles

Zinc oxide (ZnO) is a class of inorganic metal oxides available and exhibit a wide range of nanostructures. It is known as II–VI semiconductor [40], since Zn and O are classified two and six in the periodic table, respectively. It is characterized by a direct wide band gap (3.3 eV) in the near-UV spectrum, a high excitonic binding energy (60 meV) at room temperature [41-45], and a natural n-type electrical conductivity [46].

Though ZnO shows light covalent character, it has very strong ionic bonding in the Zn–O. Its longer durability, higher selectivity, and heat resistance are preceded than organic and inorganic materials [47]. The synthesis of nano-sized ZnO has led to the investigation of its use as new antibacterial agent.

Lower cost, large surface area, white appearance and their remarkable applications in the more fields are the advantages of ZnO nanoparticles. Interestingly, ZnO-NPs are reported by several studies as non-toxic to human cells [48], this aspect necessitated their usage as antibacterial agents, harmful to microorganisms, holding good biocompatibility to human cells [39].

ZnO-NPs exhibit attractive antibacterial properties due to the increased specific surface area as the reduced particle size leading to enhanced particle surface reactivity. ZnO is a bio-safe material that possesses photo-oxidizing and photocatalysis impacts on chemical and biological species. Emphasize was given to bactericidal and bacteriostatic mechanisms with focus on generation of reactive oxygen species (ROS) including hydrogen peroxide (H_2O_2), OH^- (hydroxyl radicals), and O_2^{-2} (peroxide). ROS has been a major factor for several mechanisms due to the electrostatic binding of the particles on the microbial surface contributing to the antimicrobial activity of ZnO nanoparticles [49].

Photocatalytic activity of ZnO nanoparticles offers a promising method for wasted water treatment [50]. Toxic water pollutants released from textile and dying industries by utilizing natural source of energy, sunlight is degraded by ZnO and exhibit photochemical reactivity. This could be because of the presence of many active sites and fabrication of hydroxyl radicals on ZnO surface. They exhibit high catalytic efficiency, strong adsorption ability, being used in sunscreens manufacture [51], ceramics and rubber processing, wastewater treatment, and fungicide [52-53]. ZnO nanoparticles can absorb both UV-A and UV-B radiation and therefore offers better protection and improved opaqueness [52].

2.1. ZnO nanoparticles green synthesis

ZnO nanoparticles have been reported to be synthesized from many plant extracts. In Azadirachta indica, stabilizing agents for the nanoparticle synthesis are flavanones, terpenoids and reducing sugars, the constituents of the Neem leaf broth [4]. It is suggested that the aldehyde groups are responsible for reduction of zinc oxide to zinc oxide nanoparticles and stabilize the nanoparticles [4].

Noorjahan *et al.* proposed a method to synthesize zinc oxide nanoparticles from the leaf extract of Azadirachta indica and lipseste un verb its characterization by FTIR and SEM analysis. It was seen that from FTIR analysis, alcohols, terpenoids ketones, aldehydes and carboxylic acid were surrounded by synthesized nanoparticles. SEM analysis showed stable zinc oxide nanoflakes and spindle shaped nanoparticles. The size of the ZnO nanoparticles synthesized was found to be 50 μm [54].

Sangeethaa *et al.*, depict Aloe vera has immuno-modulatory, anti-inflammatory, UV protective, antiprotozoal, and wound- and burn-healing promoting properties. Single crystalline triangular gold nanoparticle (~50-350 nm in size) and spherical silver nanoparticles (~15 nm in size) in high yield have been successfully synthesized [55]. This synthesis is by the reaction of aqueous metal source ions (chloroaurate ions for Au and silver ions for Ag) with the extract of the Aloe vera plant. Aloe vera extract was used to synthesize Spherical zinc oxide nanoparticles and their optical properties were studied [55].

Murraya koenigii has been reported to have hypoglycemic [56] and anti-fungal effects [57] and against colon carcinogenesis [58]. The plant has active agents like polyphenols and flavonoids, which have strong roles in the synthesis and stabilization of metal NPs [59-61]. The other authors reported that the contents of polyphenol and flavonoids present in the leaf of M. koenigii are 81.9 mg Gallic acid equivalent g/L and 39.98 mg of quercetin g/L, respectively. These compounds act as reducing agents and as the stabilizing agents by adhering on the surface of the NPs formed, and thereby prevent their aggregation and control the particle size [59-61].

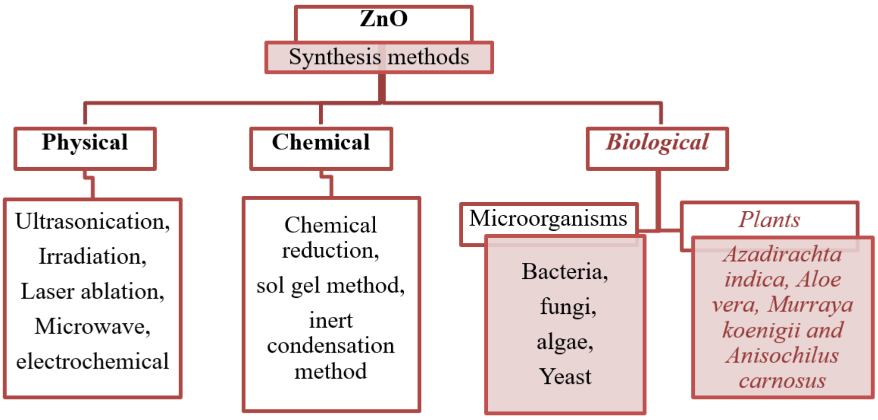

Fig. 1. *Methods involving nanoparticle synthesis*

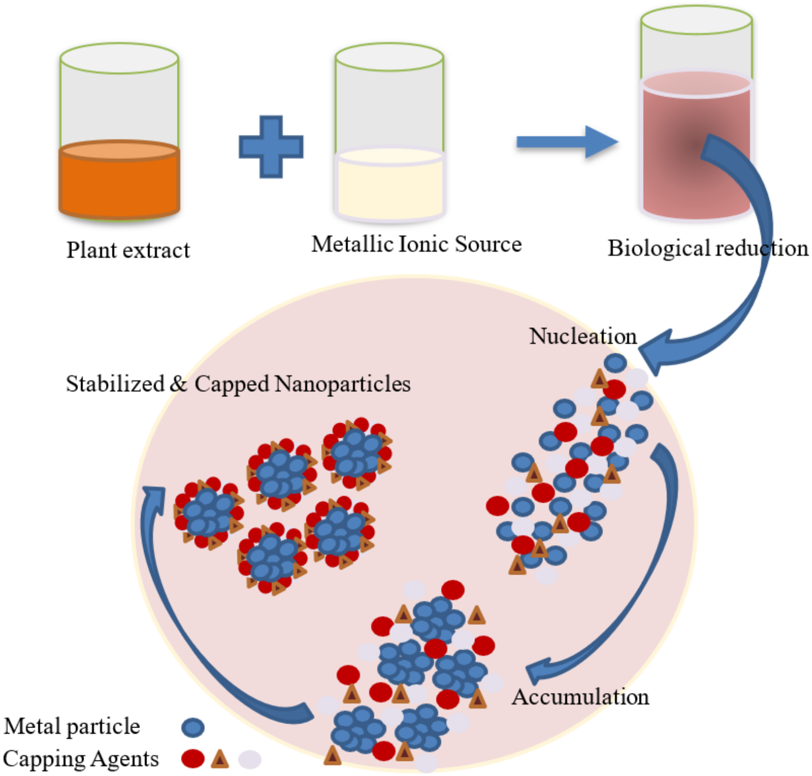

Fig. 2. *Schematic representation of mechanism for biological synthesis of nanoparticles using plant extract*

2.2. Antibacterial activity of ZnO nanoparticles

Elumalai and Velmurugan reported the MIC, MBC and MFC values of prepared ZnO NPs against bacteria and fungi. Significant inhibition by the ZnO NPs was seen against S. aureus, B. subtilis, P. aeruginosa, P. mirabilis and E. coli and fungi strains such as C. albicans and C. tropicalis with distinct differences in the susceptibility to ZnO NPs in a dose dependent manner. Among them, S. aureus was found to be more susceptible to ZnO NPs [62].

The mean zones of inhibition ranged from 9.8 ± 0.76 to 23 ± 0.50 (mm). The highest mean zones of inhibition ranged from 14.4 ± 0.76 to 23 ± 0.50 (mm) against S. aureus. The MIC values ranged between to 6.25 to 50 (µg/mL) and MBC and MFC from 12.5 to 50 (µg/mL).

Antimicrobial activities of ZnO NPs increased with increase of concentrations (50, 100 and 200 µg/mL) and were due to the increase of H_2O_2 concentration on the surface of ZnO.

Lakshmi *et al.* have reported the antibacterial study of zinc oxide nanoparticles synthesized from Aloe vera hot extract (ZnO-AH), cold extract (ZnO-AC) and chemical method (ZnO-C) on six clinically isolated strains namely, Bacillus subtilis, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Salmonella typhi and Staphylococcus aureus. Significant activity was seen in the zinc oxide particles synthesized by chemical method and particles obtained using Aloe vera cold extract. ZnO-AH showed less activity.

There was a significant difference in the antibacterial activities of ZnO-AH and ZnOAC though both synthesized in a similar manner. This variation was because of the size as the size of ZnO-AH is much more than that of ZnO-AC. The smaller the size of nanoparticles, the better is their activity [63-64].

Mariam *et al.*, reported a novel synthesis for In_2O_3 and ZnO nanoparticles with particle sizes in the range of 10 to 30 nm using indium nitrate and zinc nitrate solutions. They utilized A. vera extract as a solvent instead of organic solvents. The antibacterial and antifungal activities of the particles were studied using S. aureus, S. pyogenes, P. aeruginosa, E. coli, and S. typhi and the fungal strains were A. niger, A. flavus, A. fumigatous, Rhizopus indicus and Mucor indicus. Highest inhibitory activity against the tested bacteria was displayed by the extracts with ZnO + In_2O_3+ A. vera. A. bigger growth was also inhibited by the extract. It was concluded that ZnO nanoparticles mixed with A. vera were effective in inhibiting bacterial growth [65].

Elumalai *et al.*, reported that to study the antimicrobial activity of the leaf extract of Murraya koenigii the bio-assay was carried out using five bacterial strains such as S. aureus, B. subtilis, P. aeruginosa E. coli, P.mirabilis and two fungal strains such as C. albicans and C. tropicalis as per the disc diffusion and dilution technique. It was concluded that the zone of inhibition increased with increase in zinc oxide nanoparticle concentration and decrease in particle size. The ZnO-NPs were found to be effective for both S. aureus and E. coli and P.aeruginosa [62].

Anbuvannan *et al.* reported the ZnO nanoparticle synthesis and antibacterial activity of Anisochilus carnosus. Antibacterial activity was studied against the Gram-negative and the Gram-positive bacteria S. paratyphi, V. cholerae, S. aureus, and E. coli. Inhibition zones of 6 mm, 10 mm, 7 mm and 9 mm were observed from the synthesized ZnO nanoparticles against S. paratyphi, V.cholerae, S. aureus, and E. coli, respectively. In the present study, green synthesized ZnO NPs exhibited a greater significant zone of inhibition compared to leaf extract and solvent [66].

4. Conclusions

The green synthesis of ZnO nanoparticles is an interesting subject of Nanomaterials Science. Also, of the latest concern it is the biosynthesis of metal nanoparticles using plants to obtain them on a large scale. Nanoparticles produced by plants are more stable and more varied in shape and size in comparison to those produced by other organisms. In this review, the synthesis of ZnO nanoparticles and antimicrobial activity were reported. The ZnO nanoparticles have varied applications in all fields. The enhanced bioactivity of ZnO nanoparticles is attributed to the higher surface area to volume ratio. The antimicrobial activity of ZnO nanoparticles was reported with respect to Azadirachta indica, Aloe vera, Murraya koenigii and Anisochilus carnosus. Therefore, based on the reported antibacterial and antifungal activity, it can be concluded that the ZnO nanoparticles constitute an effective antimicrobial agent against pathogenic microorganisms.

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IBUPROFEN: ORIGINAL VERSUS GREEN SYNTHESIS

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ABSTRACT

This paper makes a parallel between the original route versus the green route of Ibuprofen (non-steroidal anti-inflammatory drugs most commonly recommended) synthesis. The original route contained six steps with stoichiometric reagents (some reagents are very toxic: hydrochloric acid, ammonia), a lot of intermediate products, relatively low atom efficiency equal to 40.04% and substantial inorganic salt formation (aluminium trichloride hydrate). The green route of Ibuprofen synthesis developed only three steps, a lower amount of waste and by-products (only acetic acid that can be used for another applications) and an atom efficiency of 77.44%. The green route for Ibuprofen synthesis is an exquisite example of a simple and elegant chemical/pharmaceutical manufacturing process and the nearly complete atom utilization of this streamlined process truly makes it a waste-minimizing, environmentally friendly technology.

KEYWORDS: Ibuprofen, green synthesis, atom economy, environmentally friendly

1. Introduction

The pharmaceutical industry is one of the most dynamic sectors of the chemical industry for this century. In a report conducted by the Centre for Responsive Politics, there were more than 1,100 lobbyists working in some capacity for the pharmaceutical business in 2017. In the first quarter of 2017, the health products and pharmaceutical industry spent 78 million dollars on lobbying member of the United States Congress [1].

The anti-inflammatory and analgesic drugs are a category of medicines which are produced every year in a very large amount. The most important medicines used as anti-inflammatory and analgesic are: Aspirin, Acetominophen (Paracetamol) and Ibuprofen. The last one is currently one of the most common over-the-counter medicine used as analgesic-antipyretic-anti-inflammatory drugs for treating pain, fever and inflammation because Ibuprofen is probably the least toxic, being rarely associated with deaths from accidental or deliberate ingestion or with serious adverse reactions [2-5].

In 2011 the most commonly recommended NSAIDs (non-steroidal anti-inflammatory drugs) were: Aspirin (88 countries), Ibuprofen (90 countries), Diclofenac (74 countries), Indometacin (56 countries) and Naproxen (27 countries) [6].

Ibuprofen (Fig. 1) was discovered in 1955 in United Kingdom, in 1958 the compound code named BTS 8402 is given to a clinical trial (i.e. a trial on patients), in 1961 it was patented with the name 2-(4-isobutylphenyl) propanoic acid, today called Ibuprofen.

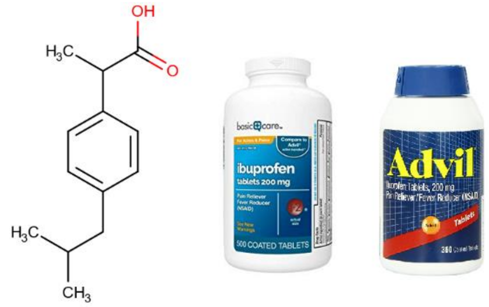

Fig. 1. *Ibuprofen-NSAIDs drug with sales increased constantly in last decades*

The compound was synthesized by pharmaceutical company Boots from United Kingdom, in 1969 clinical trials of Ibuprofen are launched in the United Kingdom on prescription only and from 1983 Ibuprofen was available without medical prescription. The medicine was recommended to be prescribed at up to 2.4 g/day (or higher dose in the USA) for the treatment of musculoskeletal pain and inflammation as well as other painful conditions [7, 8].

Green chemistry is the practice of chemical science and manufacturing in a manner that is sustainable, safe, non-polluting and that consumes minimum amounts of materials and energy while producing little or no waste material.

Together with green chemical engineering, green chemistry must propose and modify or totally redesign chemical products such as: all materials involved in making a product should be incorporated into the final product, the use or generation of substances that pose hazards to humans and the environment should be avoided, the use of auxiliary substances should be minimized and preferably totally avoided, energy requirements should be minimized, products that must be dispersed into the environment should be designed to break down rapidly into innocuous product [9-13].

From the green chemistry point of view, the original synthesis of Ibuprofen generates a lot of dangerous waste and by-products, the energy was consumed with lower yield of the final product, so that it was necessary to improve or to modify the route of Ibuprofen synthesis.

2. Ibuprofen synthesis

2.1. The original route for obtaining Ibuprofen

The originally route, developed by the Boots Pure Drug Company-United Kingdom (the discoverers of Ibuprofen) contained six steps for Ibuprofen synthesis with stoichiometric reagents, relatively low atom efficiency and substantial inorganic salt formation (Fig. 2) [14].

It can be observed that the classical route uses from the first step aluminium chloride in a stoichiometric amount, which is then converted into aluminium trichloride hydrate waste. Another disadvantage for this method is the number of steps for obtaining the final product. So that, the six steps used for synthesis leads to auxiliary products that are not found in the final product, since the atom efficiency is lower.

Another negative result of this route that results from numbers of steps is energy efficiency. A lot of steps used for the final product synthesis imply a lot of energy quantities, so that the energy consumed is retrieved in the final price of the product. A lot of steps are used to obtain the final product involving a lot of catalytic reagents and intermediate products that are not reused at the final of steps.

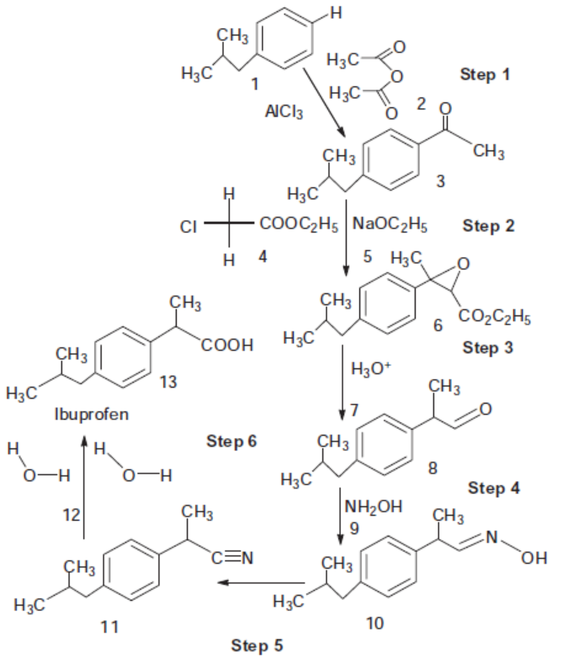

Fig. 2. *The classical route for Ibuprofen synthesis used by Boots Company* [14]

Atom economy or atom efficiency (A.E., %) is an important parameter for green chemicals equations. In ideal reaction, the atom economy is 100%, it means no waste, no by-products and that all reagents were used to obtain the final product.

The atom economy was calculated with equation [15]:

$$A.E.(\%) = \frac{mass\ of\ atoms\ in\ desired\ product}{mass\ of\ atoms\ in\ reactants} \cdot 100$$

In Table 1 were given the same parameters used to calculate the A.E. for each step of reactions for Ibuprofen synthesis under classical route (reagent chemical formula, relative molecular mass of reagents and relative molecular mass of used products).

From the data presented in Table 1 it could be observed that for the first step, the A.E. was 74.58%, without calculating the mass of $AlCl_3$ used as catalyst from Friedel-Crafts reaction that cannot be reused because this catalyst become waste after reaction.

The second step of reaction used three reactants and the atom economy was 71.49%. It is important to mention that sodium ethoxide used as reagent was obtained in-situ from sodium hydroxide dissolves in excess of ethanol (solvent).

The green chemistry principles mention that auxiliary substances (e.g. solvents) should be made unnecessary wherever possible and innocuous when used [16]. More than that, sodium ethoxide is extremely flammable, harmful and corrosive (Dangerous Substances Directive 67/548/EEC).

Table 1. *The atom economy (%) for classically route of Ibuprofen synthesis and parameters used to calculate him*

Reactions steps	Reagents chemical formula	Relative molecular mass of used reagents	Relative molecular mass of used products	Relative molecular mass of by-products or waste	Atom economy, %
Step 1	$C_{10}H_{14}$	134.0	176.0	60.0	74.58
	$C_4H_6O_3$	102.0			
Step 2	$C_{12}H_{16}O$	176.0	366.5	104.5	71.49
	$C_4H_7O_2Cl$	122.5			
	C_2H_5ONa	68.0			
Step 3	$C_{16}H_{22}O_3$	262.0	281.0	91.0	67.61
	H_3O	19.0			
Step 4	$C_{13}H_{18}O$	190.0	223.0	18.0	91.93
	NH_3O	33.0			
Step 5	$C_{13}H_{19}NO$	205.0	187.0	18.0	91.22
Step 6	$C_{13}H_{17}N$	187.0	182.0	17.0	92.38
	H_4O_2	36.0			

For the step free of the reactions for Ibuprofen synthesis using the classical route, the atom economy is lower than the first and second steps, with a value of 67.61%.

It can be observed from Table 1 that the atom economy for the step four is higher, with a value of 91.93%.

However, it is important to mention that the hydroxylamine used as reagent may explode on heating. Another negative aspect for this reagent is: hydroxylamine is an irritant to the respiratory tract, skin, eyes and other mucous membranes. It may be absorbed through the skin, it is harmful if swallowed and it is a possible mutagen. More than that, hydroxylamine is dangerous for the environment [17, 18].

On the step five of the classical method for Ibuprofen synthesis the intermediate product is a nitrile and the atom economy is 91.22%.

The last step of the route obtaining for Ibuprofen was an atom economy of 92.38%.

For the entire process it was observed that it was used only 206.0 relative molecular mass from the total relative molecular mass of reagent with a value of 514.5, 308.5 relative molecular mass was lost as waste or by-products.

If the analysis of the entire process for Ibuprofen synthesis using the classical route we can conclude some aspects: the process involved 6 steps, it was necessary 13 intermediate reagents for obtaining the final products, some reagents are very toxic, with a high negative impact on the environment, a lot of products were by-products or waste (hydrochloric acid, ammonia, acetic acid and aluminium trichloride hydrate).

Hydrochloric acid can cause skin burn, eye damage and irritation to different parts of our bodies (Dangerous Substances Directive 67/548/EEC). Ammonia is not toxic for human body, but it is toxic for fish and amphibians and if waste is thrown into water, a ecological disaster will happened [19].

The six steps of Boots reaction for obtaining Ibuprofen needs a lot of energy consumption because most of the reactions require heating.

The last, but not the least disadvantage of the classical route for Ibuprofen synthesis is the atom economy of the entire steps with a value of 44.04%, a very low value under green chemistry principles that generate a lot of waste.

2.2. The green route for Ibuprofen synthesis

In the 1980’s was developed o new route for Ibuprofen synthesis, a green one with only three steps of reactions, involving a lower amount of waste and by-products, only seven intermediate reagents, most of them reused, and a higher atom efficiency than the classically route.

The green route was developed by the Boots-Hoechst-Celanese (BHC) Company (United States of America) (Fig. 3) and the process won the Kirpatrick Chemical Engineering Achievement Award in 1993 and the Presidential Green Chemistry Challenge Award in 1997 [20].

Table 2 presents same parameters used to calculate the atom efficiency for each step of reactions for Ibuprofen synthesis under green route (reagent chemical formula, relative molecular mass of reagents and relative molecular mass of used products).

It can be observed from Table 1 that from the first step of reactions with green route, the atom economy has the same value, 74.58% with the first step of reaction with classical route of Ibuprofen synthesis from isobutylbenzene and acetic anhydride.

But, the first step of reactions from green route is possible with hydrogen fluoride used as a catalyst and solvent for the reaction that can be recovered and reused repeatedly [21].

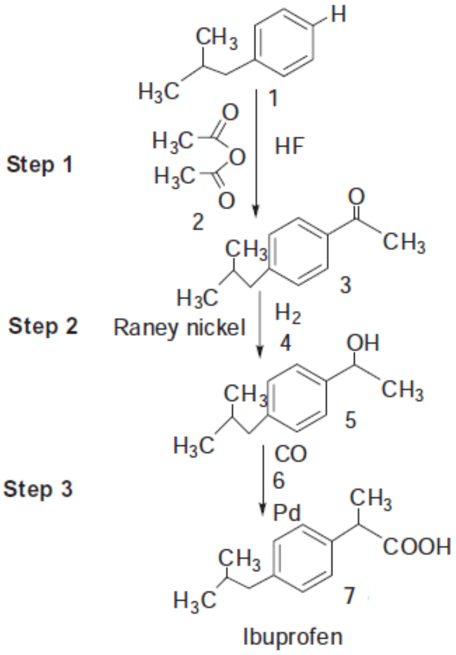

Fig. 3. *The green route for Ibuprofen synthesis used green process* [20]

In BHC process the bath recycle times and capital expenditure are lesser when compared to Boots process. The result is increased economic benefits of company and non-polluted reagents. More than that, the hydrogen fluoride is the single solvent used for green Ibuprofen synthesis, simplifying product recovery and minimizing fugitive emissions.

If it is considered that the acetic acid obtained as by-product from the first step of the reaction is used for another applications, the atom economy for step one with green route is 100.00%.

The second step of the green route is reduction of a ketone to an alcohol with an atom economy of 100.00%. The catalyst used was Raney nickel (spongy nickel), a fine-grained solid composed mostly of nickel derived from a nickel-aluminium alloy with stability and high catalytic activity at room temperature [22].

The last step of reactions for Ibuprofen synthesis using the green route represents carbonylation of alcohol over a Pd as catalyst that can be recycled and reused [23]. The atom economy of the final step was 100.00%.

For the entire process it was observed that was used 206.0 relative molecular mass from the total relative molecular mass of reagent with a value of 266.0 (only 60.0 relative molecular mass was lost under acetic acid form), so that the atom economy of the entire processes for Ibuprofen synthesis using green route was 77.44%, almost double versus the value of the atom economy of the process using classical route.

Table 2. *The atom economy (%) for green route of Ibuprofen synthesis and parameters used to calculate him*

Reactions steps	Reagents chemical formula	Relative molecular mass of used reagents	Relative molecular mass of used products	Relative molecular mass of by-products or waste	Atom economy, %
Step 1	$C_{10}H_{14}$	134.0	176.0	60.0	74.58
	$C_4H_6O_3$	102.0			
Step 2	$C_{12}H_{16}O$	176.0	178.0	0.0	100.00
	H_2	2.0			
Step 3	$C_{12}H_{18}O$	178.0	206.0	0.0	100.00
	CO	28.0			

The green route for Ibuprofen synthesis is an exquisite example of how a simple and elegant chemical/pharmaceutical manufacturing route, initially a route with a lower atom economy can be made much cleaner, much favourable and much economical through implementation of green process technology.

If we consider that about $7.2 \cdot 10^3$ tons of Ibuprofen are produced each year [11] we can imagine how waste is not produced, a lot of energy is not consumed, and the process does not pollute the environment.

3. Conclusions

Observing Ibuprofen synthesis under the green chemistry principles it could be concluded that the original route was performed in six steps, with the productions a lot of by-products, a lot of waste, enormous quantities of energy consumed and serious damage of environment.

Synthesis of Ibuprofen under original route was an atom efficiency of only 40.04%.

The green route, the Boots-Hoechst-Celanese process provides an elegant and efficient solution to a prevalent problem encountered in bulk pharmaceutical synthesis. The amount of waste is minimum (only three steps for reactions comparing with six steps in classical route), the catalyst and solvents are reused and recovered, the energy consumption is lower comparing with classically route.

The atom economy of entire processes for green synthesis of Ibuprofen is 77.44% and it lost only 60.0 relative molecular mass under acetic acid form. If this by-product is reused for another application, the atom economy becomes 100.00%.

The nearly complete atom utilization of this streamlined process truly makes it a waste-minimizing, environmentally friendly technology.

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NON-CONFORMITIES ANALYSIS IN THE INDUSTRIAL MANUFACTURING PROCESSES

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ABSTRACT

The current article presents the identification, treatment method and encoding of causes that generate defects and types of non-conformities encountered during the manufacturing process in industry.

The analysis is performed periodically: monthly, quarterly, yearly, compared to the results of previous similar periods. This process is the basis for establishing the necessary corrective/ preventive measures.

The purpose of this study is to show how to achieve data centralization needed to prevent non-quality.

KEYWORDS: industry, turbine components, non-conformity, Quality Plan (QP), Corrective Action Report (RAC)

1. Introduction

This article aims to analyse how to deal with non-conformities occurring in the manufacturing of turbine components, generators and compressors used in energy industry.

Each company, through the entities involved, plans and develops the processes necessary to deliver the products contracted in accordance with the design documentation and the contractual requirements [1]. The product planning activity starts with the analysis of the customer's requirements through calls for proposals and contract proposals. Output data of the customer requirements analysis determines the quality objectives, product requirements and processes, specific documents and resources expressed through the Quality Plan-QP and the technological documentation [2]. Providing verification plans at the reception desk based on risk strategies known and accepted by all the entities involved in the production process to ensure delivery to the beneficiary of the contractually agreed quality [3, 4, 12].

2. Method

The Quality Plan-QP is used to keep checks on the activities carried out and to provide records on their performance. Its requirements are developed from the early stages of the implementation activities, identifying the sequence of the inspections and tests steps required to demonstrate the fulfilment of the requirements, the means by which they are verified, and the acceptance criteria [5]. It is thus possible to demonstrate permanently the control of the checks made and of the issued registrations.

The records are necessary to provide evidence that the manufacturing processes and the resulting product meet the requirements, in accordance with the technological documentation, constructional design documentation and customer requirements.

2.1. Opening the non-conformity report

The organization must ensure that the non-conform product is identified and kept under control to prevent unauthorized use or delivery.

The analysis of the treatment of non-conformities will be made based on the methodology for identifying, registering, completing, disseminating, circulating, tracking and solving Non-Conformity Reports – NR issued as a result of non-conformities to products and services [4].

Control personnel who identify the nonconformity and initiates NR need to know the domain and range of products under manufacturing as well as the type of possible non-conformities.

Execution staff, upon finding a non-conformity, immediately stops the execution of the landmark (if possible) and announces the job manager and the Quality Control Department staff to analyse the non-compliance and prepare the NR [4].

These NR are forwarded to the Non-Compliance Analysis Commission, whose component and competence is established based on an internal decision, according to the requirements of the Integrated Management System. Analysing and solving RNs is an ample process involving management personnel; due both to the costs of eliminating non-compliance and to the need to obtain certain approvals/exemptions.

If the nonconformity is found to be due to a failure of the machines or equipment used to obtain the product, then the activity will be stopped immediately, requiring reconditioning and repair [6, 7].

In order to identify and track the non-conform product, it is necessary to record its data from the technological documentation, the existing marking on the part and the codes from: the list of the codes of non-conformities causes; a list of defects codes; a list of job codes; a list of existing machine codes within the company.

Determining the cause and defect code that generated the non-conformity is performed by the inspector within the workshop where the non-conformity was found.

2.1.1. Documents of non-conformity report

For the dimensional deviations are made measurements sheets, drawings, passports, which are attached to the NR and are mentioned therein [9, 10].

For deviations identified by visual inspection (see Fig. 1), chemical analysis, mechanical tests, hydraulic or pneumatic probes, the records issued (test bulletins, photo if defects are visible – see Fig. 2) are attached to the NR and are also mentioned therein.

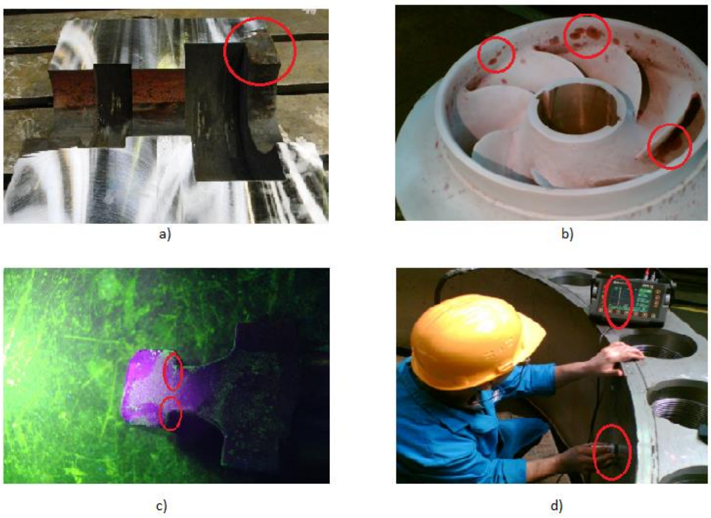
a) b) c) d)

***Fig. 1.** Non-conformities identified following inspection: a) visual; b) penetrating fluids; c) magnetic powders; d) ultrasound*

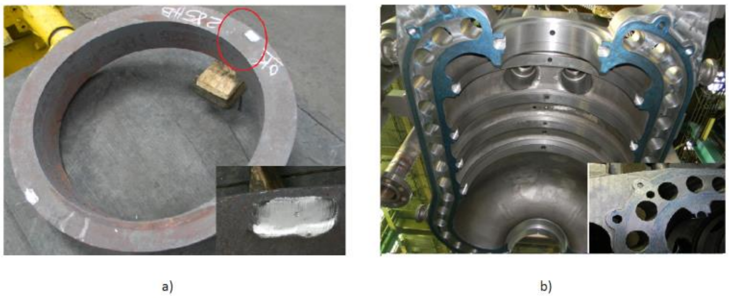
a) b)

***Fig. 2.** Non-conformities identified after: a) Brinell hardness testing; b) Sealing testing (pneumatic test)*

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After registering the non-conformity identification data and its description in the NR, the Quality Control Department determines whether the non-conformity found is repeatable to initiate corrective actions to prevent recurrence of similar non-conformities [13, 14].

Framing of non-conformity is done by the product engineer, as follows [17]:

- Scrap;
- Repair/ reprocessing [5] – can be returned to the project requirements (description of the solution);
- Acceptance without modification – no longer meet project requirements;
- Conditional acceptance – description of the required conditioning.

Filling in chapters and NR circulation is performed according to the framing of the non-conformity, as follows:

a) Non-conform product – scrap

For rebutted products the financial records, the costs generated by non-conformity will be operated and the production department will work in order to transfer the product to the scrap storehouse (if the product is not over-sized).

b) Non-conform product that can be brought to the project requirements by repair / reprocessing

Following the analysis of the NR by the Commission, the product engineer will launch a number of additional operations to resolve the non-conform product, operations that are always completed with a control operation, as a result of which the product may continue to flow or be discarded, depending on the result of this control.

c) Non-conform product that is being promoted with established deviations (conditional acceptance or acceptance without modification)

There are situations when the non-conformity cannot be removed, especially in the case of oversized products, and the cost of repatriation is extremely high. In these situations, a Request for Derogation is drawn up following a meticulous analysis of the project, a request which will be approved by the Non-Compliance Analysis Commission and which will eventually reach the client for acceptance.

2.2. Opening the non-conformity report

Following the analysis of the annexes to NR and the company's strategy for reducing and preventing the occurrence of non-conformities, the Coordinator of the Nonconformities Analysis Commission writes the necessary comments for the improvement of the process [14]. His opinion at the closure of the NR attests the fact that all the departments involved in the nonconformity analysis and resolution have solved their specific tasks [15, 16].

After the closure of the NR, it is analysed by the Nonconformities Analysis Commission. The NR can also be analysed during the resolution of the nonconformity by the various compartments involved in the solution. The analysis also includes the number of non-destructive examination controls performed, the Corrective Action Report, RAC, issued, the number of Requests for Exemption, the number of products approved for manufacturing, the data necessary to establish the specific trends of the various processes involved, the general data needed for the analysis, the number of open NR monthly etc.

3. Case study

Table 1 shows a defect-generating pattern coding model.

Table 1. *Encoding defective causes*

Code	**Defective cause**	**Cause description**
0	1	2
01	*Execution planning*	The process of developing the manufacturing plan is inappropriate, resulting in an error in the technological sheet, the technological scheme, the worksheet or the working instructions; lack of execution documentation.
02	*Communication*	Inappropriate presentation of information, whether spoken or written.
03	*Inappropriate technical documentation*	Inappropriate design style, without complying with standards or technical standards; non-updated documentation; inadequate documentation of the technological flow and product requirements.
04	*Parameters of the technological operation*	Working parameters (speed, speed rate, feed, cutting depth, etc.) are not defined, monitored or measured; non-observance of the

		working parameters of the established technical requirements. For special processes: non-observance of the indicated parameters (voltage, current, temperature, time, machinery, monitoring, etc.) and/or the execution phases and inter-operational control.
05	*The technological process*	Technological capacity (capability) is not able to generate the product according to drawing or documentation; failing to meet the specified product requirements; non-correlation of the technological sheet with the Quality Plan; non-compliance with contract requirements.
06	*Cutting tools*	An error caused by the cutting tool that breaks, cracks, presents deviations from the machining axes, is incorrectly sharpened, is used over the length of use between two sharpening, etc.; lack of cutting tools indicated in the execution documentation.
07	*Machine tool*	Working parameters that do not ensure the conditions imposed on the product; presents unforeseen failures during execution, numerically controlled/inadequately controlled or inadequate product to be executed.
08	*Fixtures or clamping devices*	Improperly chosen/unprotected or damaged.
09	*Measuring systems and devices*	Erroneous measurements due to lack of maintenance, inappropriate exploitation, or erroneous calibration/ verification.
10	*Electrical parameters*	The product's electrical parameters are inadequate to the required requirements.
11	*Management decisions*	Errors due to omitted operations, inappropriate programming/ordering/choice of technology or due to a decision that deviates from the instructions of the execution and/or control documentation or other specified requirements.
12	*Major force*	Errors caused by fire, voltage drop or other unforeseen factors. Human error is excluded.
13	*Climatic factors*	Errors caused by execution at low/high temperatures, humidity, inadequate or excessive lighting, noise etc.
14	*Storage (includes stock items)*	Inappropriate storage or preservation (rust, surface defects, cracks, deformations, non-destructive controls, etc.); the disappearance of identification marks due to improper storage conditions. Failure to observe the shelf life of the applied materials, failure to perform periodic inspections of the protection before and during storage.
15	*Personnel training/ qualification*	Incomplete or inadequately qualified personnel for the execution of the planned operations; not properly trained for current work.
16	*Human error*	Execution documentation, instructions, or technical procedures for the related processes have not been followed, or any deviations of the staff from the specified requirements have been worked out, resulting in non-conformities.
17	*Handling / Packing / Preservation*	Error caused by inappropriate handling, packaging and/ or conservation (on the products to be delivered).
18	*Documentation control*	Inappropriate distribution, circulation and retention of technologies, instructions, procedures, drawings and other documents, or the lack of quality documents required for executed products.
19	*Suppliers control*	Failure to observe the procedure of choice, approval, qualification and supervision of suppliers = hidden vices of the material; defects resulting from the technological process of material preparation and treatment (casting, forging, rolling, moulding, etc.). It also includes defects on delivered products that require further reshuffle/ reprocessing within the company.
20	*Material replacement*	The material required by the documentation is not available or does not meet the required conditions.

22	*Problems caused by the client*	Existing defects in parts, subassemblies, or materials that have been made available by the customer and not included in the Minutes of Finding or accompanying quality records (including their hidden vices) [18].
23	*Special processes*	Welding, thermal treatments, thermostabilizing, creep, dyeing/ coatings, etc., which do not meet the established requirements or do not lead to the requirements imposed on the product.
24	*Product not received*	Product entered in the execution process without qualitative reception
25	*Resource assurance*	Missing Tools and Verification Devices (TVD) indicated in the documentation; lack of measurement and monitoring devices; lack of consumables (oil, emulsions etc.), lack of equipment needed for technological support; inappropriate human resources [19].
26	*Customer benefit*	Includes non-conformities to products executed by the company, but due to the collaboration between the customer and the client, by performing works directly at the company's headquarters.

Table 2. *Encoding defective causes*

Code	**Class defects**	**Defect**
0	1	2
A.	*Constructive design defects*	1. Incorrect or incomplete specification 2. Incorrect or incomplete specified material 3. Requiring inappropriate specific technology documentation 4. Component of the product improperly specified 5. Inappropriately specified procedures and applications 6. Inappropriate drawing detail 7. Incorrect dimensional specification 8. Non-specification of deviations in form and position in drawings 9. Highlights identified inappropriately in the project 10. Conflict of specifications in the drawing 11. Inadequate project documentation requirements 12. Incorrect adaptation or non-adaptation of external documentation
B.	*Technological design defects*	1. Incorrect or incomplete specified material 2. Inappropriately specified size 3. Inappropriately specified procedures and applications 4. Inappropriate sketch detail 5. Non-specification in sketches of deviations of form and position 6. Inappropriate choice of machine tools 7. Mistaken choice of the base and catch of the piece in the device 8. The wrong choice of the base and the catch of the piece on the tool machine 9. Inappropriate indication of cutting tools 10. Inappropriate indication of the means of measurement 11. Misrepresentation or misrepresentation of cutting regimes 12. Non-specification in all technological documentation 13. the requirements in the constructive documentation 14. Specifying documents in the technical documentation that are not permanently accessible to the performer
C.	*Processing defects*	1. Dimensional deviations 2. Deviations of form 3. Position deviations 4. Deviations of balance 5. Inappropriate rug

		6. Inappropriate hole 7. Tool inlet on the processed surface 8. Traces of scratches, cuts and/ or strokes on the surface processed 9. Threaded holes with splines, broken spines, incomplete or overlapped splines 10. Absence or extra hole 11. Holes/ holes in the grille offset 12. Addition of insufficient processing 13. Use of inappropriate devices 14. Use of inappropriate tools 15. Using an inappropriate machine 16. Stepped surfaces 17.Addition of insufficient material for the finishing operation 18. Debit is wrong 19. Inappropriate deburring
D.	*Assembly defects*	1. Unassembled or omitted landmark 2. Inappropriate fitting 3. Installation made without accuracy 4. Non-compliant mounting games 5. Failure to comply with the procedural test conditions 6. Grip, scratches, scratches due to inappropriate mounting 7. Inserted an extra number of blades to the pallet operation
E.	*Defects due to special processes*	1. Product deformation 2. Inappropriate deposited/ existing layer thickness 3.Physical-chemical characteristics of the deposited/ existing layer inappropriate 4. Superficial cracks 5. Cracks in the depth of the material 6. Lack of adhesion, composition delamination 7. Welding inclusions 8. Marginal burns, burning of the base material 9. Inappropriate condition of rough surfaces (cast, forged) 10. Use of overdue term materials 11. Use of inappropriate materials 12.Faults occurring in the manufacturing process (thermostabilization, creep, etc.) other than those specified 13.Form or position of the welding cord inappropriate to the documentation 14.Feathers, voids, bumps, crevices, marginal ditches, overlapping, burns 15. Incorrect lake for electrical insulation 16. Inappropriate varnish, non-uniform coating 17. Prepare inappropriate surfaces: sand blasting outside the indicated blasting degree; incomplete or inadequate degreasing; the presence of oxides or rust on the sanded surfaces 18. Inappropriate adhesion of film coating 19. Inappropriate adhesion of metallic coatings 20. Non-uniform thickness of protection or metallic coatings (under / over imposed limits) 21. Inappropriate anti-corrosion coatings on visual control 22. Inappropriate packaging (use of materials other than those specified in the applicable documentation) 23. Conservation made with film-coated materials outside the supplier's warranty period and without recertification 24.Conservation made with materials other than those indicated in the applicable documentation 25. Use of wire, flux or electrodes with overdrive and without rectification

F.	*Material defects*	1. Certificate of non-conforming material (incomplete) 2. Deviations from specified chemical analysis 3. Deviations of the specified mechanical characteristics 4. Blows, inclusions, voids, cracks, overlaps, pores (highlighted with END controls) [20, 21] 5. Specific heat treatment improperly applied
G.	*Half-finished product defects and deviations of landmarks from customer/supplier*	1. The surface with bumps, bumps, zigzags 2. Dimensional deviations of rough surfaces 3. Nonconforming concentricity 4. No bosom, ribbing or inappropriate placement 5. Dimensional deviations, incomplete material defects and incomplete parts from customer/ supplier 6. Macrostructure and inappropriate granulation 7. Unsuitable protective or metallic coatings 8. Deviations from the specified heat treatment 9. Immature material (with a lifetime exceeding or at the technological limit/ developed according to old standards - it is used for products made available by the customer in the repairs) 10. Defects of material revealed after reception (hidden vices). Includes deviations from physico-chemical characteristics as well as defects highlighted by subsequent non-destructive controls [20]
H.	*Verification and control defects*	1. Use of a decalibrated measuring and checking tool 2. Use of an inadequate measurement and verification tool 3. Reading or interpreting error of measurement and control instrument indication 4. Erroneous entry of measured values in documents 5. Lack of product quality records 6. Lack of dimensional or visual control 7. Lack of non-destructive control
I.	*Storage and environmental defects*	1. Impairment of surfaces due to inadequate storage according to the requirements of the documentation 2. Impairment of surfaces due to expiration of the term of protection of the protection 3. Inappropriate handling of flow, wire or electrodes

4. Experimental values

The experimental results to be presented were recorded over a month in an energy equipment producing organization.

The production is a small / unique series and the main activities within this organization are the manufacture, repair reconditioning of the energy equipment or cutting operations of the semi-finished products made available by the customer, most often being large. Table 3 shows experimental values.

Table 3. *Experimental values*

Ref. no.	**No. NR/ date**	**Part designation** (object of the contract)	**Cause code**	**Defect code**	**Deviation description/ Cause presentation**
0	1	2	3	4	5
1	01/ 14.01.17	**Kaplan pallet chuck – semi-finished product** (customer's semi-finished product processing)	22	C4	Following the centering of the palette on the front track, it was found that the radial centering surface shows the following deviations: 0 to 0° on the inlet edge; 9 mm at 90°; 5.2 mm at 180° at the exit edge and 2.7 mm at 270° [6]. The cause of the nonconformity is the erroneous framing of the finished piece in the semi-finished

					product, made in the previous stage, which took place within another organization.
2	02/ 15.01.17	**Monobloc rotor** (customer’s semi-finished product processing)	16	C1	When reframing the final piece in the blank, it was found that the axial hole length of 1345 mm would result in 1190 mm, the diameter of the hole being the one desired, Ø76. The cause of noncompliance is because the existing additions to the rotor end have not been considered.
3	03/ 16.01.17	**Bowl** (customer’s semi-finished product processing)	16	C7	The piece shows a tool inlet on the tilted flank of the thread, appearing in the milling-thread operation. The cause of the occurrence is to block the machine-tool and move it only one axis, not two axes as it did before.
4	04/ 21.01.17	**Kaplan pallet chuck** (customer’s semi-finished product processing))	16	C5	The roughness of 1.6, on the Ø1470 e6 diameter, according to the execution drawing, was made of 2.13 ÷ 2.71 and the diameter between Ø1469.72 ÷ 1469.74 mm. The cause of the occurrence is the lack of a grinding operation.
5	05/ 21.01.17	**Inferior + superior piston’s labyrinth-holder** (Repair/ Reconditioning)	5	G5	In the finishing turning operation pore appeared in the composite material cast on this surface, and the Ø 445 mm was made of Ø 451.6 mm. The cause of the occurrence is the lack of technology verification, human error.
6	06/ 23.01.17	**Kaplan pallet chuck – semi-finished product** (customer’s semi-finished product processing)	21	C7	At customer’s request there was a gap from the workpiece’s axis for Ø117 mm holes, which generated 7 tool inlets on a 170° arc with a width of up to 12.82 mm and a depth of 0.5 mm. The cause of the occurrence is the cancellation of the requirement by the customer after starting the respective processing operation.
7	07/ 23.01.17	**Inferior + superior pallet-holder** (Repair/ Reconditioning)	16	C1	Dimension of 10-0.04 from the 6 channels has been performed at 9.83 ÷ 9.84 mm [6]. The cause is given by the operator who measured with a micrometer without considering that the rod surface measuring instrument is flat and machined surface is cylindrical.
8	08/ 24.01.17	**Front bearing box** (customer’s semi-finished product processing)	16	C9	In two of the threaded holes M30 the caliber enters with “no go” side, along the whole thread length (gap). The cause of the occurrence is due to the use of an inadequate tool, human error.
9	09/ 27.01.17	**Pallet chuck** (customer’s semi-finished product processing)	16	C1	The "G3" hole in the execution drawing, (drawing dimension Ø210 + 0.115) was made at the Ø210.56. The cause is given by difficult access to the surface and use of inappropriate tools.
10	10/ 27.01.17	**Lower valve bush** (execution)	19	F4	The parts show defects (microcracks) highlighted by the LP control, according to the LP no. 67/2017. The cause of the occurrence is the choice of an inappropriate blank from the stock.

Solving these nonconformities was done as follows:

- for RN 01 / 14.01.17 - Kaplan pallet chuck - semi-finished product: the part is accepted as such, the customer obtaining the approval of its final customer, based on the DDR Exemption Application No. 2 / 30.01.17;
- for RN 02 / 15.01.17 - Monobloc rotor: verification and marking of add-ons for confusion elimination [7, 8];
- for RN 03 / 16.01.17 - Bowl: Edge adjustment and acceptance as such, based on the DDR Exemption Application No. 1 / 22.01.17. The piece has been inspected with LP [9] on the adjusted areas and adjacent surfaces;
- for RN 04 / 21.01.17 - Kaplan pallet chuck - semi finished: the revision of the technology. Immediate polishing of the surface, without affecting the diameter, a minimum diameter of Ø1469.70 mm is accepted, based on DDR Exemption Application No. 3 / 30.01.17;
- for RN 05/ 21.01.17 - Inferior + superior piston labyrinth-holder: Composite material return and repeat operation [10];
- for RN 06/ 23.01.17 - Kaplan pallet chuck - semi-finished product: the part is accepted as such, based on DDR Nr. 4/ 30.01.17;
- for RN 07/ 23.01.17 - Inferior + superior pallet-holder: designer's solution: realization of the labyrinth sealing area, of the rotor counterpart, consequently with the erroneous quotation on the pallet;
- for RN 08/ 24.01.17 - Front bearing box: designer's solution: Thread increase at M35;
- for RN 09/ 27.01.17 - Pallet chuck: acceptance as such diameter Ø210.56 conditioning counterpart execution to the hole dimension, based on the request for derogation DDR No. 5 / 02.01.17;
- for RN 10/ 27.01.17- Lower valve bush: New part execution.

5. Conclusions

Following the non-compliance reports that occurred during the month presented above, the following improvement proposals were done:

- additional training of staff involved in Kaplan blades processing, to improve the manufacturing process of these types of parts;
- improving the working environment by auxiliary measures, such as additional lighting of workplaces;
- simulation of numerical control programs, before starting each phase of an operation;
- additional measurements during the operations;
- acquisition of non-destructive tested semi-finished products, in prior;
- increasing the annual number of audits performed at suppliers;
- all reports submitted were closed in less than 30 days.

The Annual Analysis highlights the number of NR issued by codes of cause and defect, specifies the number of NR remaining open at the date of drawing, that year and separately in previous years, to ensure a pertinent analysis of the trend of nonconformities and their causes. Coding nonconformities gives the possibility to be classified at any time, with the following benefits: intervening on the processes in a timely manner, by further training of staff; taking additional precautions: Pokayoke; obtaining data for performing FMEA analyses; fault tree; lowering the cost of non-quality.

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THE ENVIRONMENTAL IMPACT ASSESSMENT OF A MUNICIPAL LANDFILL - A STUDY ON THE LEACHATE

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ABSTRACT

The increase in consumption draws the need to quickly assess the problem of the municipal solid wastes. On the short term, the easiest way to deal with this stringent problem seems to be landfilling. This method was always a controversial one. Thus, making it more environmentally friendly was the logical next step. The recovery and utilization of methane gas, the recovery and treatment of the liquid generated by the landfill and, finally, the sealing of the landfill by the end of its utilization made it possible to deal the waste problem more environmentally friendly. However, no matter how “green” a landfill might be, every time such type of site is planned, a thoroughly environmental impact assessment must be conducted to anticipate, avoid and ameliorate the impact on the environment. This paper presents some aspects regarding an environmental impact assessment of a landfill, focusing mainly on the possible impact on water, the effect of leachate treatment and, finally, the future alternatives to landfilling.

KEYWORDS: environmental impact; leachate; municipal landfill

1. Introduction

The problem with waste management keeps getting more severe due to the alarming increasing of quantity and their impact on the environment. The increase of human population induces resource consumption due to higher production creating a significant environmental impact through wastes. In Romania, final disposal of municipal waste represents the primary option. Almost 98% of this kind of wastes are disposed yearly in specially arranged places named municipal landfills [1].

Any landfill that is about to be constructed or existent must be subject to a rigorous analysis ant also has to adopt the best measures regarding the environmental protection reducing thus its impact.

Although municipal solid waste landfilling might be easier and more frequent due to low costs during construction, operation and closing, compared to recycling costs, it can impact greatly the environment in time. Badly designed or exploited landfills can create almost always more serious consequences to the environment than non-complying ones and the areas surrounding the landfill might become heavily polluted. Landfills might pollute the air, water or soil since in such a badly designed or exploited construction the dangerous chemical substances present the risk to infiltrate in the environment. Also, frequently, the fauna is attracted to landfills and can spread dangerous diseases endangering the population around the site [2].

The methane gas, the leachate and the bulk municipal waste are the three main challenges of landfilling. The methane gas is produced in a landfill through anaerobic decomposing and can be collected with the existing technology then used to generate electricity in the landfill site or elsewhere or can be purified and then used as fuel for power generators. The leachate is a thick liquid, formed during waste decomposition. In the best-case scenario, the leachate is similar to residual waters and in the worst-case scenario it can transport dangerous materials dissolved from the wastes situated in the landfill. Landfills are equipped with synthetic liners placed on a layer of clay soil that helps to prevent leachate drain in underground water, preventing contamination [3, 4].

A municipal waste landfill also comes with some advantages. The first would be the possibility to obtain energy through methane gas conversion. Landfilling all non-recycling wastes in the same, controlled and monitored place, avoiding the non-complying methods would be another advantage of this procedure. Also, the construction of a landfill creates new jobs during and after its activity [5, 6].

Leachate collection from a landfill is done using a system consisting in a web of perforated pipes from the base of the landfill, situated in a layer of sand under the deposited waste [7, 8]. The purpose of the present work is to assess the environmental impact of a landfill, from the point of view of the possible transmission of pollution through leachate generation.

2. Materials and methods

The leachate is created in landfills through leaching of wastes in different putrefaction states and the precipitation water. Water is infiltrating in the waste layers, dissolving and engaging a wide range of compounds. The leachate is usually collected in a basin, treated in a treatment plant for phosphorus and heavy metals retaining then is pumped in the sewage system or in a water-body if all the norms are met. According to the actual legislation, leachate treatment can be realized using two types of systems: i) using a treatment plant owned by the landfill that will permit the leachate evacuation directly into a natural receiver in compliance with the relevant legislation; ii) using a leachate pre-treatment facility prior to discharging into a municipal waste water treatment plant, respecting the values of the effluent quality indicators. Unfortunately, presently in Romania, there are still some non-complying landfills that do not has neither of the two leachate treatment systems mentioned above. Part of the European Union legislation was assumed by Romanian national legislation. Thus, the leachate collection methods refer only on the complying landfills. There is no method describing the leachate collection for non-complying landfills [9].

To start the experiment, an untreated leachate sample and a treated leachate sample were taken to determine their chemical and physical composition. Figure 1 presents the two basins used to contain the abovementioned sample types.

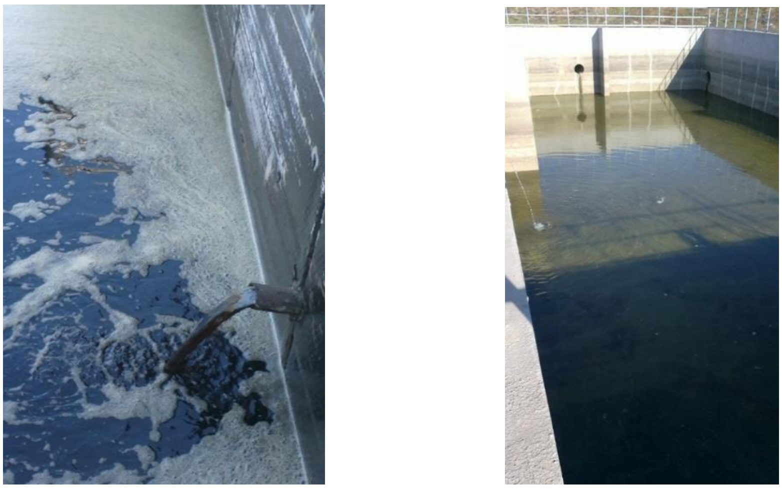
a b

***Fig. 1.** Leachate collection basins: a - before and b – after treatment*

The equipment used consisted of: sample collection recipients, laboratory glassware, portable multiparameter model Aquatest +MO (HACH-LANGE), for pH values determination; UV-VIZ/VIZ spectrophotometer, model: DR 5000 (HACH-LANGE), for chemical factors determinants and an incubator for CBO_5 determination.

3. Results and discussions

For the leachate to be evacuated in the nature its chemical composition must be followed some maximum values established through corresponding legislation. The most important typical limits are found in Table 1, together with values for leachate samples before and after treatment. The treatment plant is owned by the landfill and is based on the reverse osmosis principle.

In Table 1 the most dangerous concentrations of the untreated leachate can be observed. These values must be reduced through whatever methods and brought as close as possible to the admissible values before safely discharging in the environment. After the treatment process some concentrations decreased consistently, even more than the maximum admissible values. The concentrations for suspended matters, CCO-Cr, Ammoniacal nitrogen, Phosphorus and Heavy metals (Pb, Cd, Cr, Cu and Zn) suffered major transformations, reaching extremely low concentrations. To further highlight the difference between the two types of samples and between the two and the maximum admissible values, several graphs were drawn for the pollutants considered the most harmful for the environment.

Table 1. *Parameters values for leachate before and after treatment compared to maximum admitted values*

Nr. crt.	Indicator	Measuring unit	Untreated leachate	Treated leachate	Maximum admissible value
1	pH	pH units	8.28	6.94	6.5
2	Suspended matter	mg/L	215	17	60
3	CBO_5	mg/L	327	20	30
4	CCO-Cr	mg/L	2102	72.7	500
5	Ammoniacal nitrogen	mg/L	58	0.6	30
6	Phosphor total	mg/L	4.95	0.3	5.0
7	Pb	mg/L	0.44	0.06	0.5
8	Cd	mg/L	0.65	0.02	0.3
9	Cr total	mg/L	1.79	0.05	1.5
10	Cu	mg/L	2.19	0.05	0.2
11	Zn	mg/L	1.73	0.09	1.0

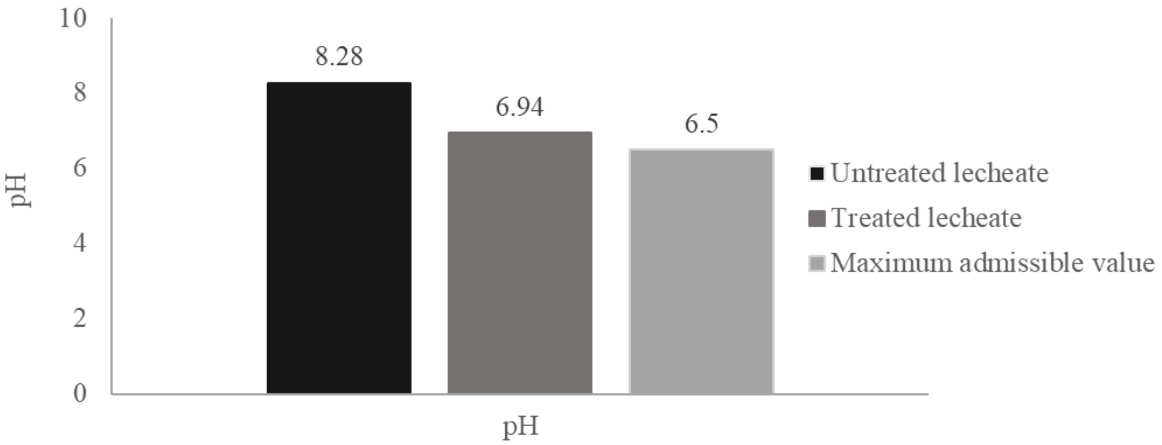

Fig. 2. *pH values of the leachate samples before and after treatment compared to the admitted value*

Figure 2 represents the modification of pH value after leachate treatment by a reduction with 1.34 pH units from the initial state. In the present case, after treatment, the leachate reaches a value close to the maximum admissible limit of 6.5 pH units, however even after treatment this limit is exceeded. In such situations, when the values after treatment do not comply with the maximum admitted values, the leachate should not be discharged directly into nature and further treated.

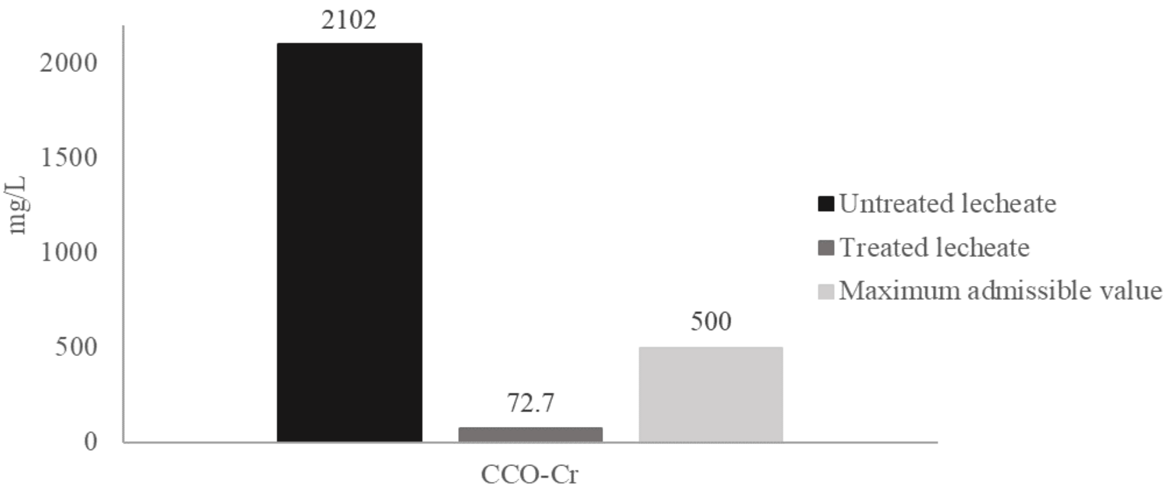

Fig. 3. *The amount of chemical oxygen demand for leachate samples before and after treatment compared to the admitted value*

The biggest difference between samples (treated and untreated) is that regarding CCO-Cr. In this case, the untreated leachate presents a value of 2102 mg/L and after treating this value falls with 2029.3 mg/L, reaching a value of 72.7 mg/L. Compared to the maximum admissible value (500 mg/L), after treatment, the CCO-Cr value for the leachate gets to decrease almost seven times. Thus, from this point of view the leachate might be discharged in nature without a major risk.

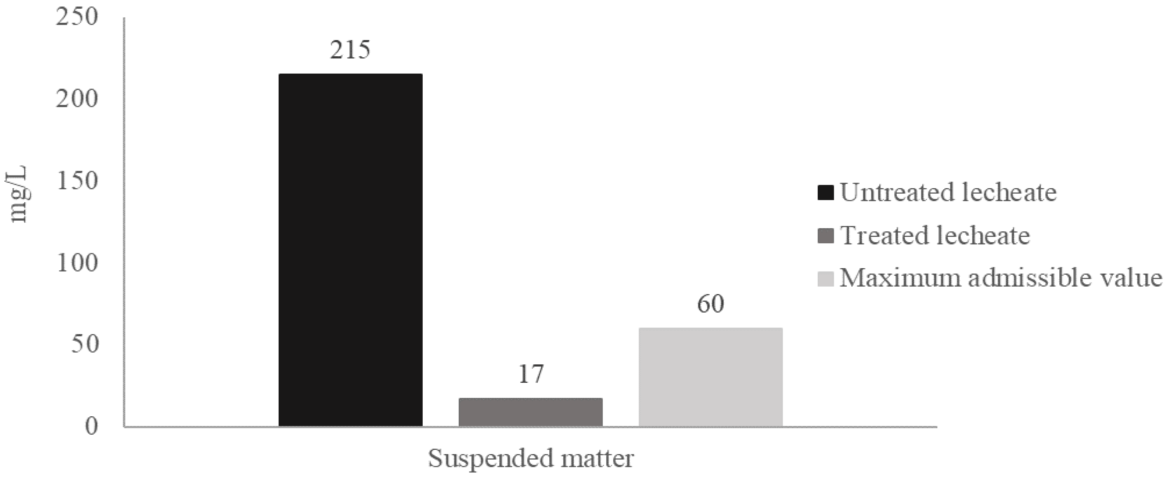

Fig. 4. *The value of suspended matter for leachate samples before and after treatment compared to the admissible value*

The suspended mater (Figure 4) represents the insoluble substances in the leachate. These are found in a very high concentration in the untreated leachate. After treatment, the suspended mater decreases considerably with 198 mg/L, which represents a big advantage for the environment.

The CBO_5 parameter (Figure 5) represents a measure of organic impurification of residual waters and is the quantity of oxygen (mg/L) needed to oxidize the organic substances through bacteria. Before leachate treatment, the CBO_5 content is significant, decreasing with 307 mg/L, reaching a value of 20 mg/L, a value smaller than the admissible one.

Regarding the heavy metals content of the leachate, from the examples abovementioned it is shown that after treatment the leachate has a lower content, compared to the admissible value. Out of the three examples, the largest content for the untreated leachate belongs to Copper, with a 2319 mg/L content. After treatment, this value decreases with 2.19 mg/L reaching the lowest value, namely 0.2

mg/L. The content of Zinc and Lead after treatment has also decreased considerably. Thus, the value for Lead decreased with 0.38 mg/L reaching under the admissible value and the Zinc value decreased by 1.64 mg/L.

The leachate is a liquid that cannot be discharged in nature without treatment. Its toxicity is detrimental to the health of the creatures with which it comes into contact, from the infiltration site to where it is spread through the groundwater. The leaching treatment should be based on an optimal solution, considering the actual conditions on the ground, the composition of the leachate, the climatic conditions, the available surface, and the impact of the technology on the environment [10-13].

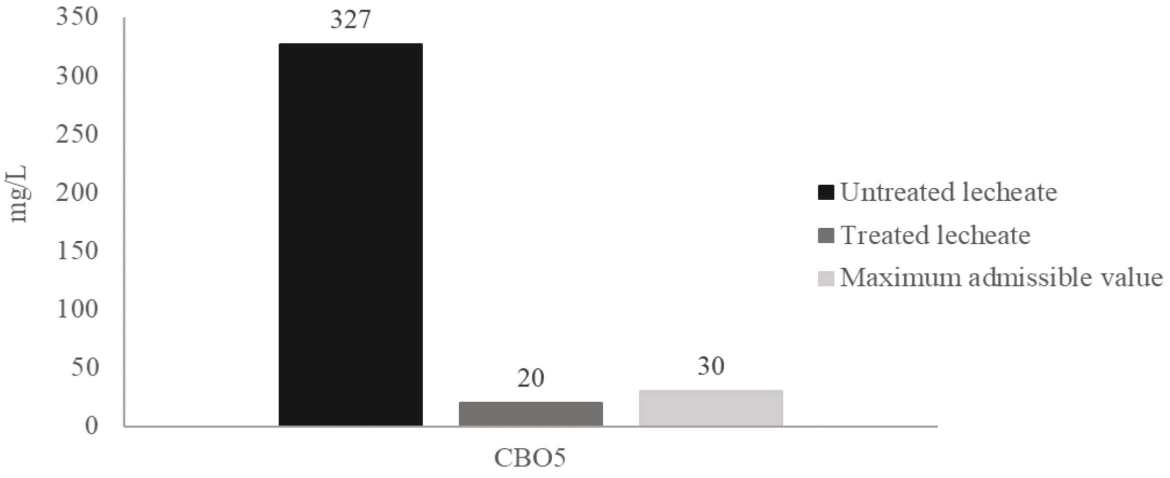

Fig. 5. *Biochemical oxygen consumption value for leachate samples before and after treatment compared to the admissible value*

Following the leachate treatment, it was found that almost all concentrations decreased considerably. For example, concentrations of CBO, total nitrogen, ammoniacal nitrogen, total Cr, Cd, Cu, decreased by over 90%. A major advantage of leachate treatment is that certain substances can be completely removed depending on the nature and quantity of the leachate. For example, Sodium, Potassium, Calcium, Magnesium and Sulphate have been totally removed. Components found in untreated leachate appear after treatment in a lower or no concentration, which proves that the eventual impact after treatment is low. Concentration decreasing rates are different for different chemicals. The readily soluble and biodegradable substances reach the highest maximum concentrations, the moment when reaching the maximum value being closer to the start of the landfill operation.

4. Conclusions

From the beginning of the construction to its closure and even after, a municipal solid waste landfill may have a negative impact on the environment. Firstly, it affects the landscape with visual discomfort and creates new forms of relief by excavation and deforestation. The equipment used for different processes during the landfill construction also has harmful effects on the environment through oil, fuel and even some construction materials. At the same time, the air might be polluted by generating dust and traffic emissions on the site. Also, flora and fauna can be endangered because once the work starts, their habitat can be removed, fragmented or separated. During operation, the landfill might become a favorable habitat for different birds and animal species, considered harmful and dangerous to the community near the deposit. The environment is disturbed by the equipment noise, the mud on the roads, and the smell characteristic of a landfill due to decomposing organic materials.

The main environmental impacts can be attributed to gas emissions and leachate resulting from the storage of waste in landfills, both of which can be managed through engineering. The leachate generated is a major environmental problem, therefore it must be collected and subjected to proper treatment before it is released into the environment or sewage. This study has shown the beneficial effect that a treatment plant can have on the resulting leachate. Excepting the pH, which has been slightly higher than the maximum admissible value, the other values for pollutants that can be found in the leachate corresponded to the norms after the treatment process and thus, it was demonstrated the possibility that this liquid could be eliminated directly in nature without the need for further treatment.

On the short term, landfills appear to be the cheapest and easiest option to solve the municipal waste problem, but in the long run they are a huge financial burden. This is due to the need to monitor gas from the storage site and the potential for contamination of nearby land, watercourses and groundwater for several decades after the landfill being disposed of. Taking these drawbacks into consideration, the diminishing utilization of landfills must be seriously taken into consideration in the near future and if used, landfilling should always function in parallel with a recycling program. The declared purpose of the Romanian Ministry of Environment is to stop all landfilling until 2050 and replacing it with performant programs of recycling, the only disposal being permitted in the end only to low quantities of nonrecyclable materials.

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DETERMINING THE RELIABILITY OF CLINCHER COOLERS

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ABSTRACT

For any industrial entity that is put into operation, the problem of maintaining its functioning if possible, with corresponding technical and technological parameters without failure is an important issue. This is provided by the study of the technical availability of that entity. Technical availability consists of two directions, namely: increasing the reliability, i.e. the duration of the good functioning, under operating conditions and for a well-established period and ensuring adequate maintenance. The two directions should be studied together in order to find solutions to increase the service life while reducing maintenance requests. In the present case, for the clinker coolers, only real reliability has been studied with the aim of finding practical solutions for increasing the service life. Achieving the proposed objective required the observation of the operation / failure of such a machine over nine months and the statistical processing of the information obtained.

KEYWORDS: cement industry, clinker, cooler, reliability

1. Introduction

In Romania, in 2004, the sale of cement was about 5 million tons, which corresponded to a value of approximately EUR 250 million. In 2005, the cement market was valued at 300 million-euro, accounting for 5-6% of the total construction market. In 2010, the cement market was estimated at 500 million euro, and in 2014 the local cement market was estimated at around 500-600 million euro [1].

Cement production begins in the limestone quarry, excavating limestone and clay. Then they are crushed into pieces by the size of a coin. These raw materials, together with a material that has iron intake, are homogenized in a powder called "raw meal". The raw meal is heated to a temperature of 1,450 ˚C. The high temperature turns the flour into a new material, called clinker [1].

The clinker is suddenly cooled, and then ground together with gypsum in a fine powder. This is Portland cement. To produce different types of cement, slag and/or ash of thermal power (material resulting from the combustion of coal or other mineral materials) is added. Therefore, clinker coolers are the main machinery in cement making technology, and the study of their faultless operation is an important objective.

On the other hand, firing and cooling of the clinker is the most important part of the cement manufacturing process, which raises key ecological problems in terms of nitrogen and sulphur oxides and dust emissions.

This brief introduction shows how important is the study of cement manufacturing technology in general, and clinker equipment in particular.

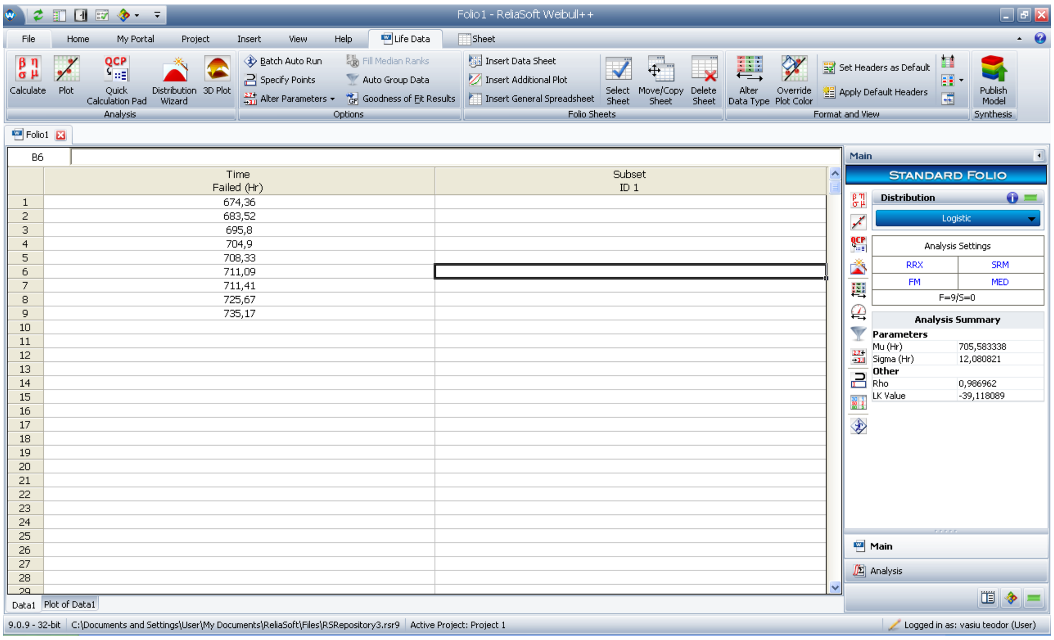
2. Collection and processing of experimental data

In order to accomplish the proposed goal, the operation / failure of a clinker cooler was monitored for nine months. In [2] recommendations on observation duration are made. Good running and maintenance times were recorded on special papers.

Because we are concerned only with reliability, good running times have been considered and introduced into the Weibul++9 specialized software [3]. The good operating times entered in the program are shown in Figure 1.

The chosen software has the possibility of an analysis that provides the optimal distribution law for each case, i.e. the mathematical law with the maximum correlation coefficient between the experimental and the theoretical data.

For reliability, good running times respect logistic law (Fig. 2) with a correlation coefficient Rho = 0.986962. The parameters of this law are: average μ = 705.583338 hours and the location parameter (standard deviation) σ = 12.08021 hours (Fig. 1).



B6

	Time Failed (Hr)	Subset ID 1
1	674,36	
2	683,52	
3	695,8	
4	704,9	
5	708,33	
6	711,09	
7	711,41	
8	725,67	
9	735,17	

Distribution: Logistic

Analysis Settings: RRX, SRM, FM, MED, F=9/S=0

Analysis Summary

Parameters	
Mu (Hr)	705,583338
Sigma (Hr)	12,080821
Other	
Rho	0,986962
LK Value	-39,118089

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Fig. 1. *Good running times*

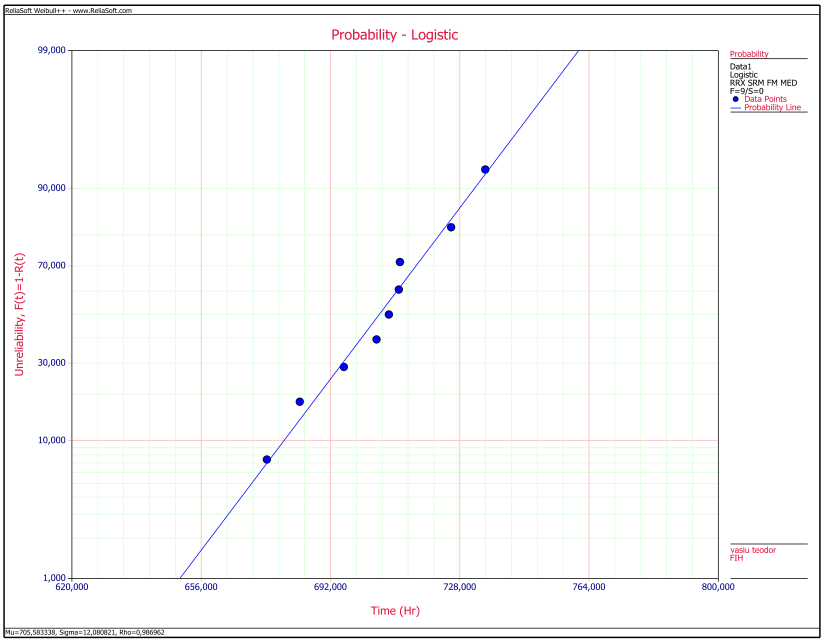

Fig. 2. *Probabilistic diagram of the logistics function*

Because the logistics law is not one that often appears in the reliability and maintenance studies, it is considered necessary to present this law. Logistics distribution has been used to model prototype operations but has also been useful in shaping the normal life of industrial entities. The form of logistics distribution and normal distribution are very similar. There are opinions that claim that the logistics distribution is inappropriate for lifetime modelling because the left limit of the distribution extends to -∞. This could theoretically lead to negative operating times until failure. However, provided that the distribution in question has a relatively large average and a relatively small location parameter, the problem of negative times should not disturb.

The probability density of the logistic distribution is [4]:

$$f(t) = \frac{e^{z}}{\sigma(1+e^{z})^{2}}$$

$$z = \frac{t-\mu}{\sigma}$$

$$-\infty < t < \infty, \quad -\infty < \mu < \infty, \sigma > 0 \quad , \qquad (1)$$

where t [Hr] is the time of proper functioning.

3. Interpretation of the obtained results

There are not general rules to interpret statistical data, so everyone's experience is important [5, 9].

Figure 3 shows that the cooler's reliability is kept close to 1 for about 660 hours. This time may be a guarantee period for maintenance work; that means, it is incredible that any defect will occur within 660 hours.

This can also be seen in Figure 4 where the probability of failure (non-reliability) is close to zero, 660 hours after the cooler is commissioned.

The graph (Figure 5) of the logistic distribution probability density supports the assertion that the shape of logistic distributions and Gauss are similar.

The failure rate (Figure 6) of the cooler is low for about 660 hours, which is expected in the light of the developments in Figures 3 and 4 and will soon increase.

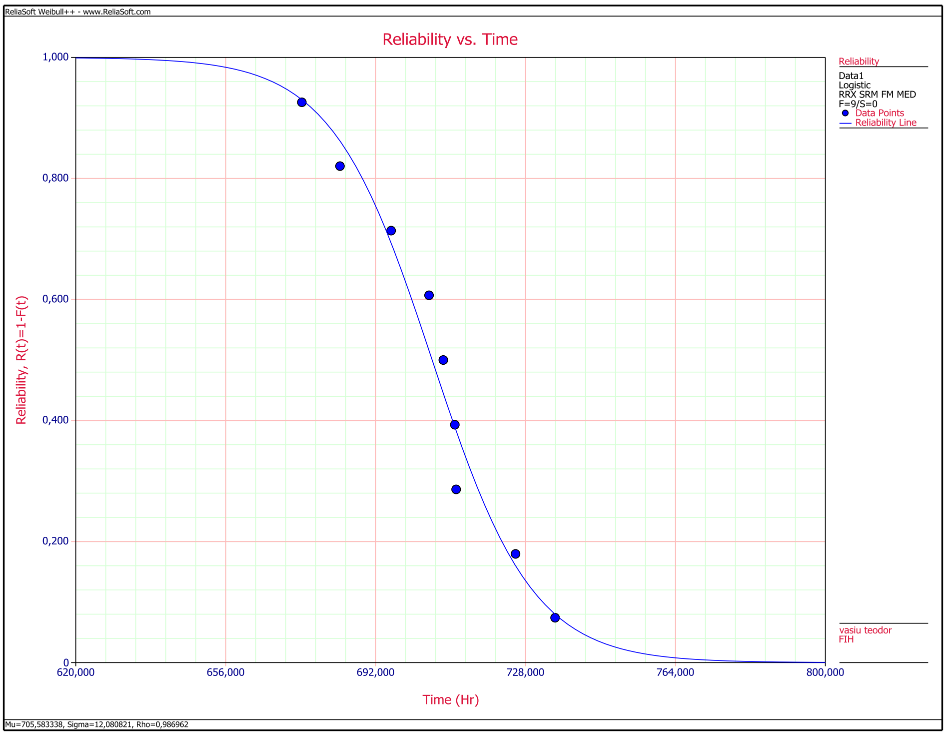

Fig. 3. *Reliability versus time*

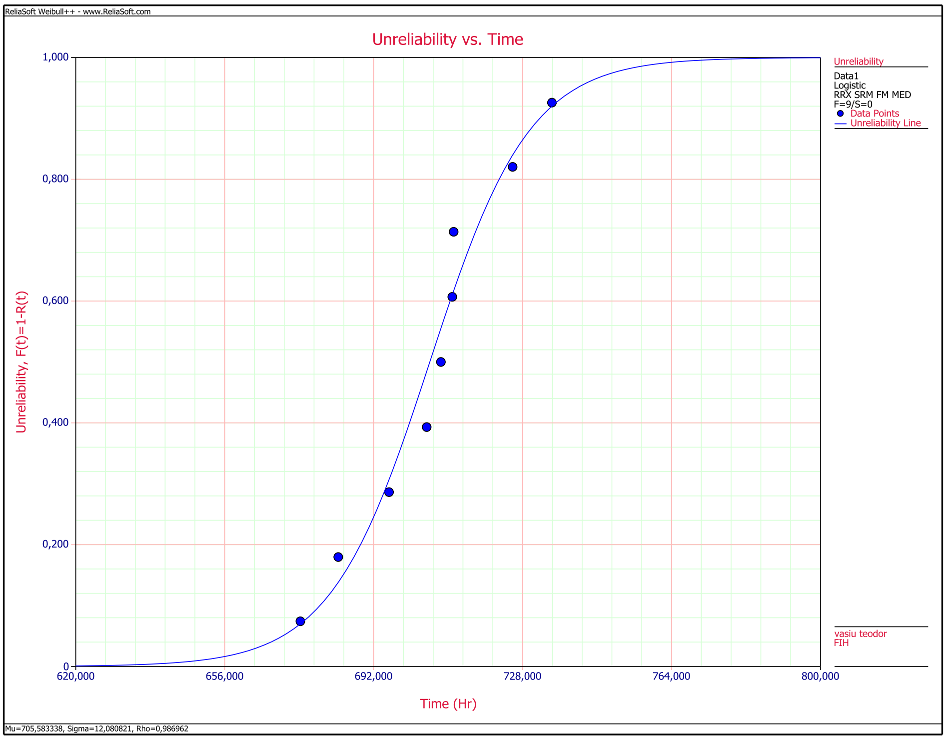

Fig. 4. *Non-reliability versus time*

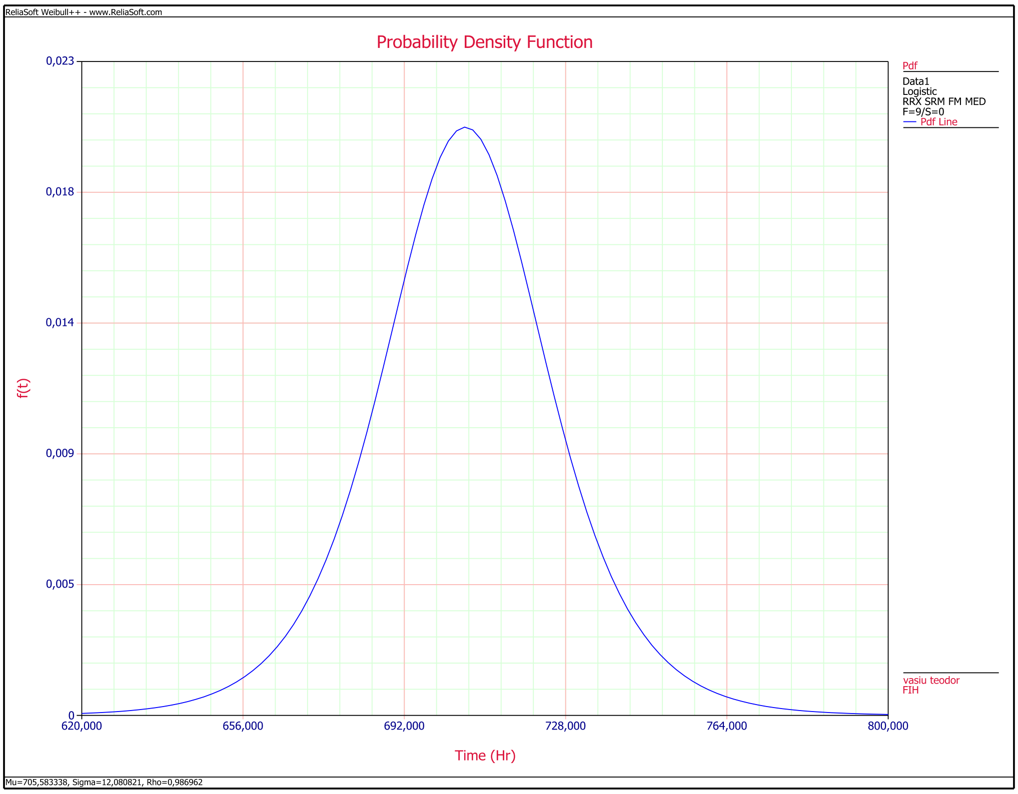

Fig. 5. *Probability density of logistics distribution*

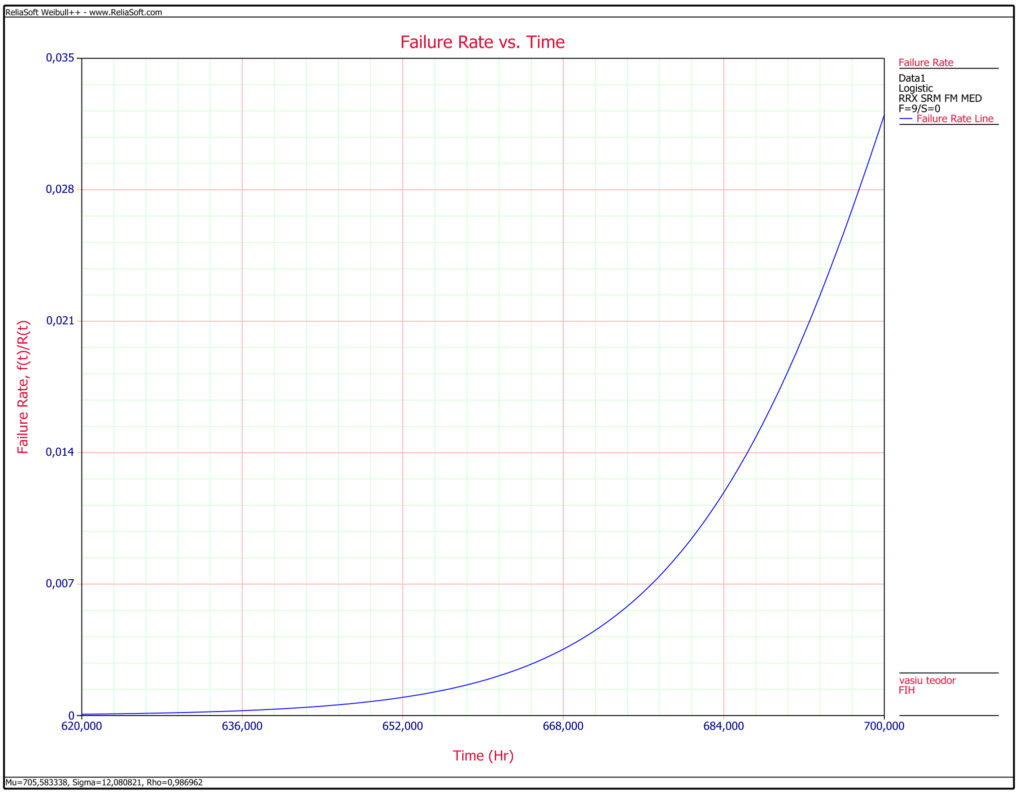

Fig. 6. *Failure rate versus time*

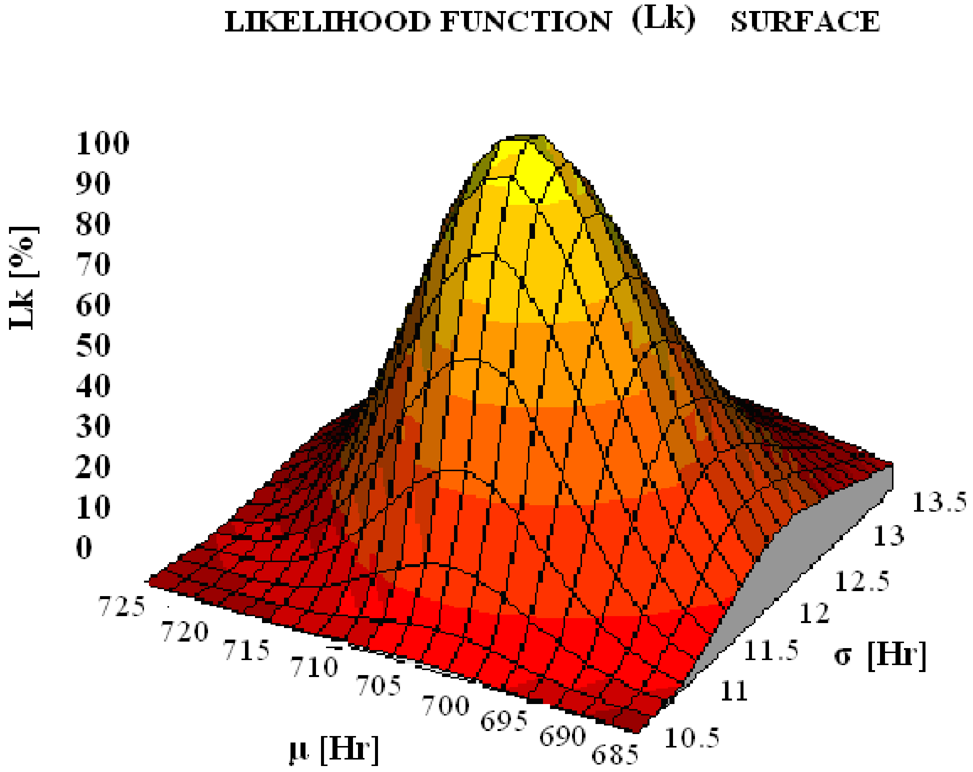

Fig. 7. *Likelihood function of maximum verosimilitude*

The maximum verosimility function Lk (Fig. 7) shows that the values determined for the logistic law parameters are most probable, i.e. the pair of values $\mu = 705,583338$ hours and $\sigma = 12,08021$ hours determines a maximum of the Likelihood function.

In statistics, a Likelihood function (often simply a likelihood) is a function of the parameter of a statistical model given data [10]. Likelihood functions play a key role in statistical inference. In informal contexts, "likelihood" is often used as a synonym for "probability". In statistics, the two terms have different meanings. Probability is used to describe the plausibility of some data, given a value for the parameter. Likelihood is used to describe the plausibility of a value for the parameter, given some data.

In this case, the Likelihood function has the form:

$$\mathbf{Lk} = \prod_{\mathbf{i}=1}^{9} f\left(\mathbf{t_i}, \boldsymbol{\mu}, \boldsymbol{\sigma}\right) \qquad (2)$$

where t_i, i = 1, 2, ..., 9 are the values of the good functioning times in figure 1, and *f* is given by the relation (1).

The expression (2) can be used both to determine the parameters μ and σ, imposing the maximum condition for Lk, and to check if the parameters obtained by other paths maximize the function Lk. This time, the second option was preferred.

4. Conclusion

The 660-hour time, determined by statistical calculations of experimental data, is an important value in the life of the cooler. During this time the reliability is maximum and the failure rate minimum. The technical-organizational actions (procedures, infrastructure, adequate qualification of maintenance and exploitation personnel, etc.) should be directed towards increasing this time. The final scope is to keep the cooler in operation for as long as possible so that the technological flow of cement production is not disturbed.

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PATENT ENFORCEMENT: A COMPARATIVE REVIEW PREVENTING PATENT TROLLING IN EUROPE

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ABSTRACT

The US has made significant progress in the patent legislation landscape as evidenced by the US Patent Act in the Constitution and America Invents Act (AIA) of 2011. Nevertheless, patent suits by non-practicing entities (NPEs) have been on the increase over the past ten years. Major corporations, especially, such as Apple and Samsung have been on the receiving end of the litigation as NPEs target their large cash holdings. A closer look at the patent laws in the US and Europe reveals subtle differences in the grace period, publication of patent, and the application of patent rights across member states. Given the preceding facts, vital action points for the European market include the enactment of laws that prevent patent trolls as opposed to punishing NPEs after the act and reduction of litigation costs for low-quality patents.

KEYWORDS: patent trolls, US patent laws, intellectual property, differences between EU and US laws on Intellectual PropertyNon-Practicing Entities, Intellectual PropertyNon-Practicing Entities in Europe and the United States

1. Introduction

Patent trolls are more frequent in the intellectual property (IP) space than in other areas owing to the intangible nature of intellectual property. Helmers and McDonagh [1] attribute this phenomenon to the fact that it is easier to delineate physical property and define the owner's rights than it is with intellectual property. Considering that a patent is “an exclusive right granted to a party for an invention,” IP presents an opportunity for individuals and businesses to manipulate the law and court processes [2]. While the practice is anchored in law, most patent trolls do not intend to develop or protect products as Helmers and McDonagh [1] explain. Instead, they aim at making profits and stifling competition. By conducting a thorough evaluation of patent trolls in the US economy, this study isolates crucial lessons that Europe can learn to prevent an escalation of the problem in Europe.

2. Research background

The patent system in the country has experienced a rise in patent litigation over the past decade. A 2012 study [3] examined the effects of intellectual property patents in the US. Results showed that business entities spent over $29 billion in direct costs while defending against patent infringement claims. Between 2009 and 2013, for instance, Apple defended itself against 191 patent trolls; Samsung had 151, while Dell dealt with at least 140 [4]. Likewise, the situation in Europe depicts a rise in patent suits. A study [5] of 140 small businesses in Europe revealed that as of 2015, 44% of them were affected by patent infringement cases by non-practicing entities (NPEs). These numbers presented here symbolize the actual circumstances on the ground, showing an urgent need to address patent trolling.

Such patent trolls affect the economy in wide-ranging means. The philosophy of Śledzik [4] shows that first; the sued party must spend more resources on legal fees. Second, the defendants lose significant market shares since lawsuits can adversely affect a company's reputation, on top of the legal overheads that are passed on to customers through price hikes [4]. Perhaps the highest cost is felt when the litigations impede the innovation process [3]. The US has made significant progress in tackling with the challenges over time. This paper applies the following research questions to identify fundamental lessons and action points for Europe.

1. To what extent has legislation addressed the patent troll problem in the US?

2. What are the main differences between the US and European patent law systems that non-practicing parties utilize to initiate patent litigations in Europe?

For this paper, we define certain terms as follows below.

Patent is a government-issued license that presents an inventor exclusive rights to the manufacture, use, or sale of the patented invention for a specified time period [6].

Non-practicing entities (NPEs) refers to sovereign organizations which own or benefit from patent rights but do not sell or manufacture goods or services associated with them and which have an aggressive assertion or litigative role as plaintiffs towards the enforcement of their patent rights. The organization holds a patent for a product or process without the intention of development [6].

Patent Troll. A patent troll refers to the deliberate effort by NPEs to acquire patent rights for use in suing other companies through licensing or litigation [6].

Intellectual Property. IP refers to the intangible category of property that encompasses human intellects such as trade secrets, trademarks, and publicity rights [3].

Patents cover different forms of inventions including processes and composition of matter. From the beginning, the US constitution sets the stage for patent suits in Article 1 Section 8 that state the role of the Congress in promoting innovation and useful arts by granting periods within which inventors can exercise the exclusive rights to their inventions. Bessen and Meurer [3], interpret this statement to mean an exclusive monopoly by the owner within which they can prevent third parties from using or selling the ideas. The owner’s first obligation lies in filing a patent application through the US Patent and Trademark Office after developing an invention as the authors explain. Here, the party describes the innovation in precise terms to identify which aspects are protected under the law [7]. Patent infringement occurs when another party attempts to reproduce the product as described under the law whether intentionally or not.

Although patent laws have existed for decades, patent issues have only gained increased attention in recent years. The Court of Appeals for the Federal Circuit began conducting business in 1982, according to the Introduction to Intellectual Property: A U.S. Perspective [8]. Over the years, the country has made significant steps through constructing and refining patent laws. The formation of the Federal Appellate Court to attend to patent appeals and USPTO signified a substantial success in the area. Consequently, it is now easier for patent holders to prove wilful infringement and harder for the accused to overthrow patents.

Recent interventions consist of the 2011 America Invents Act. The government intended to streamline the patent scene in the US with the rest of the world. The previous law allowed inventors to first invent the products and file during the later stages of development. Generally, the law meant that if two separate inventions were conceived at the same time, those that had the earlier date of invention received the protection. Today, the inventor who files the patent documents first gets the exclusive rights even if they do not have a previous time of invention [9]. While the change in the timelines is reasonable and achievable for most inventors, a closer look at the AIA reveals subtle counterbalances including a narrow prior art grace period, the initiation of proceedings, and a broader exception for research and shared ownership. Critics have pointed out the high fees required while filing a patent, which favours large corporations that have adequate funds to complete the processes within short periods in comparison to small businesses [10]. The argument is particularly valid for modern companies, which rely on outside funding to develop new products.

3. Research methodology

This paper uses the funnel research approach to conduct and analyse data from previous studies in support of the research questions. A thorough evaluation of the secondary sources was conducted to guarantee that each primary and secondary source is peer reviewed and that it presented data relevant to the study. Furthermore, the research presents the latest articles to assure utilization of the most recent data.

4. Results

The results section of the paper identifies issues in the US and European Union legislation which addresses the patent troll problem.

Despite the milestones that the US has made in combating the patent troll problem over the past decade, Cohen *et al.* [2] feel that the problem is yet to be adequately addressed. Four years after signing the AIA into law, 2015 recorded the highest number of patent troll cases in the country. The authors attribute this increase to the rise in technology commercialization, which precipitates action by businesses to protect their property. However, most of the cases involved NPEs whose sole intention is to create massive portfolios for use in suing other companies [3]. In a study to gauge the effectiveness of current laws in addressing the patent problem, Cohen and fellow authors [2] focused on measurable factors such as publicly traded firms, measures of firm characteristics, income, and patent holdings.

Results indicated that 59% of all patent litigations by NPEs have at least an invalid claim in comparison to 42% of the overall complaints. Second, Cohen and colleagues [2] noted a significant pattern that they named ‘forum shopping'. The pattern consists of NPEs targeting certain business areas, which has a higher certainty of attaining a return in investment. For instance, Silicon Valley recorded higher litigation dealing with patent trolls versus when compared to other industries. The NPEs also used location tactics, which have proven to be more effective. Certain US States that NPEs have deem to be plaintiff-friendly such as Texas have recorded significantly higher numbers than all other US States combined. Texas and the State of Delaware remain the most popular venues for NPE plaintiffs. The two venues accounted for 70% of all cases filed in the US and 66% of total defendants added. In the Cohen study [2], greater than 43% of all NPEs filed cases were filed in the state of Texas. Researchers observed that NPE litigations targeted companies with large cash holdings or whose fortunes had acquired them massive profits available in cash. Moreover, the study reflected that they also targeted firms with smaller legal teams with modest experience in the area. The focused-on companies that reported high profits, high cash holdings with smaller legal teams increased the potential return of investments in the litigations.

What are the main differences between the US and European patent law systems that non-practicing parties utilize to initiate patent litigation in Europe?

The Grace Period. The current US law preserves the old system's 1-year period that enables inventors at least a year to file the patent after acknowledging the invention in public. Previously, inventors could meet this objective by holding a press conference, giving a lecture about it, or presenting the idea to an investor among others [9].

Conversely, in the European Union, Kahnert [11] notes that some European Union countries attribute a 12-month grace period while others allow a six-month filing period. A 2014 study by the Europe Economic [12] investigated the significance of introducing a uniform grace period throughout the European Union. The results of the study demonstrated that the uniformed grace period would eliminate problems associated with accidental exposure of patents. Additionally, the grace period allowed the governing body additional time for market screening, testing, and improving the innovation.

Patent Publication. Article 112 of the US State code dictates that the publication of a patent must be done within 18 months of the filing date unless the owner no longer requires protection [13]. Further, the law also stipulates that a patent publication is unnecessary if the application for patent is accompanied by a non-publication request. This is a contrast between the US and European patent systems. In Europe, all patent publications are submitted within the 18-month period unless the owner withdraws the application. An earlier study [14] first confirmed the implication of the publication of the patent application law by stating that the information must remain in secret throughout the 18-month period. The request clause in the US law means that the owner has an option to keep the information private and keep competition from accessing trade secrets.

The Application of Rights. Given that the patent law is a federal statute, patented content automatically gains protection throughout all the US states. Undoubtedly, this quality heightens the ease for holders to implement the license without the need to apply again in each state. Gates [6] compares this system to the European laws where the patent applies to the 27 countries included in the European Patent Convention. They include Switzerland, Monaco, Netherlands, Romania, and the United Kingdom among others. The European Patent Office (EPO), only grants rights applicable to the EPO countries that the holder specifies in the application. Additionally, according to the EPO, patents are valid in individual countries for specified periods. Patents, therefore, are subject to the laws found in each country. If an individual, for instance, needs to annul the patent, they must do so following the requirements of each country separately [15]. Efforts to address this problem encompass the enactment of the EU Unitary Patent Package of 2011. Still, criticism regarding the fragmentation of the European Union persists.

Current US NPE related filings

Patent litigation has evolved dramatically since patent reform litigation passed in 2011. However, the US has additional patent reform changes underway, new leadership at the US Patent and Trademark Office and high-profile (and potentially high impact) cases being considered by the Supreme Court in 2018. In 2017, NPE litigation filings continued a downward decrease from the peak in 2011. 2017, NPEs related litigations were 2,000, a decrease of 27% over last year. The legal changes since 2011 have made patent enforcement more difficult. Before the legal changes, an effective validity or eligibility defence typically awaited summary judgment and thus the completion of fact discovery in district court, which was a very expensive process. In 2018, a defendant can move to dismiss a case early, on the basis of ineligibility, or can file for post-grant review and seek to stay the litigation (including the discovery process) while the Patent Trial and Appeal Board (PTAB) reviews the validity of the patent. Both options have made patent validity a threshold issue and have reduced the cost of earlier litigation stages for defendants, thereby reducing plaintiffs’ leverage early in the case. Despite the legal changes and reductions in NPE related legal filings, the quality characteristics of filings that result in more effective litigations have also increased. The assertion is derived from the observation that 59% of all patent litigations by NPEs had at least an invalid claim [2]. Also, the figures indicate a potential significant loophole in the current law since it fails to provide large corporates with the means to shield themselves from patent suits when targeted by NPEs. Cohen *et al.* [2] expressed an alarming trend regarding the forum shopping pattern. Also, seeing as the NPEs have identified states that they consider plaintiff-friendly such as Texas and Delaware, laws in such states require modifications to eliminate this perception as explained by Cohen *et al.* [2].

Study results indicate that high-profile European companies have defended themselves against patent claims with an overall increased rate since 2010. In 2010, there were 760 cases filed by NPE’s versus 1,555 in 2011, 3,059 in 2012, and 3,673 in 2013. In 2014, nearly 1,100 companies were first-time defendants in an NPE case, and when duplicates are removed from the list of defendants to any patent infringement case, 2014 saw about 3,800 unique defendants added. Large companies (by revenue) and public companies Current European Union NPE related filings have a higher rate of NPE litigation than do smaller and private companies. NPE litigation has remained the most common form of patent litigation in the EU. NPE cases accounted in 2014 for 63% of all such cases, and NPE defendants were 56% of all patent infringement defendants. The number of IPR petitions filed against NPE patents has increased over 150% from 2013 to 2014 (262 to 758). The report finds that, in the EU, NPEs prefer litigating in Germany. During the 2007-2017 period, 20% of infringement actions in Germany were NPE initiated. During the past ten years of European IP NPE related litigation has grown 19% every year, with an increased growth in 2014, 2015 and 2016.

Differences between the Two Patent Systems

The primary differences as presented in the data include disparities in the litigation grace period, the publication of patents, and the application of patent rights. The uniformity in the US system implies that a party only needs to apply for the patent with the federal government after which they can practice the rights in all the states within the country [9]. In contrast, countries within Europe ascribe to different grace periods ranging from six to twelve months, which complicates the holder’s ability to practice their rights in individual countries. In the same breath, the disparity in the provision stated in the publication of patent provides additional leeway for NPEs to exploit. Furthermore, the European system leaves additional room for exploitation through its fragmented nature [6]. The fragmentation implies that although the EPO awards the patent, it is subject to the laws of a specific country in which the holder applies.

According to a report from the European Patent Office (EPO) [15], between 2007 and 2017, the average annual growth rate of actions related to NPEs was 19%. Statistics reflect an annual increasing trend in the number of actions involving NPEs in the EU, with a dramatic increase in the last five years, primarily concerning information and communication technologies. The EPO report demonstrates that the five most active NPE company structures in the EU are based in the US. The legal filings account for 60% of NPE-related litigation in the EU. The increase in NPE litigation cases in the EU over the last five years, points to recent IP legislative changes in the US which have resulted in a reduction of prevailing cases by NPEs in the US. Similarly, to the US NPEs in the EU have a preference on where they litigate. While in the US NPEs prefer to file cases in Texas and Delaware; in the EU NPEs favour litigating cases in Germany. The EPO report reflects that during 2007 and 2017, twenty percent of infringement actions initiated by NPEs were in Germany. According to a legal review report by the German IP firm IAM-Media, Germany’s legal and judicial framework is divided within the country and infringement and invalidity legal actions are independently ruled by different courts across the country. NPEs advantaged by the shortened IP legal time process of Germany while also benefiting from rulings which are often granted prior to the finalization of legal proceedings.

5. Discussion

The findings in this study indicate an urgent need to address illicit legal filings by NPEs in the EU through legal changes or transforming the IP marketplace. EU legal filings related to NPEs between 2007 and 2016 reflect a year-to-year increase of 19%. A sharp increase in NPE cases in the EU over the last five years could be a result of recent legal changes in the US. As NPEs changed strategy, the German patent system with its brief litigation procedures and lack of up to date IP legal reforms, has emerged as the new hotspot to NPE activity. Germany lacks a pre-trial discovery or jury trials that the US provides in their system. In Germany, inspection proceedings are neither mandatory nor frequently used. Oral hearings (in comparison to trials) typically last only a few hours, rather than several days. Another attractive aspect to NTEs is the low costs of the German patent litigation, which is considerably lower than the US or other EU countries. Furthermore, following the Brexit referendum, uncertainty exists regarding the future of the EU’s new unitary patent system, which further strengthens Germany’s role as a leading venue for patent litigation.

Current laws in Europe do not address NPE litigations. While EU companies can file countersuits or attempt to mitigate their loss through existing proceedings, they take substantial loses in the litigation process and often in the disadvantageous courts which favour NPEs. Furthermore, NPEs are often shell companies that quickly dissolve and disappear without available financial resources that affected companies can go after for damages. In the US, the Innovation Act, for instance, requires mandatory fee-shifting to patent lawsuits to what the court terms reasonably justified [2]. The trends show that the law needs to provide added protection for large corporations with large cash holdings. As Cohen *et al.* [2], notes here is a pressing necessity especially in recognizing that cash holdings in segments unconnected to infringement drive NPE suits.

Another approach to the problem is to reduce the cost of defending against low-quality patents. In the US, a party can contest by claiming that the invention in question is original by showing prior art exists. However, filing such a challenge costs enormous amounts of money, meaning that easily disposable patents of such kind remain in force [2]. Also, the patent system in Europe could require that low-quality patents go through a court that conducts preliminary screening as the authors inform. An initial evaluation would likely unearth facts that can dismiss the case; that way, the advance review would help reduce NPE legal filings.

One of the primary strengths identified in the US patent system is the ability to apply patent laws equally among all the member states. Keep in mind that the significant shortcomings in the EU include differences in the grace period, publication, and the application of the application of the patent rights across member countries. By working towards an increasingly unified approach, Europe can significantly reduce the number of patent trolls [5].

Throughout the research, this study concurred with the findings by Bessen and Meurer [3] according to which the rate of patent litigation cases in the US increased significantly over the past decade despite the advancements in the legal landscape. The increase in the claims is attributed to the rise in technology advancements as companies move to protect their intellectual properties according to Cohen *et al.* [2]. The study also agrees with the findings by Cohen and fellow writers [2] that NPEs main aim while filing patent suits is to make profit rather than enhance innovations. The US has been at the forefront in developing laws regarding patent protection as depicted by Gates [6]. The study also validates the teachings by Cremers *et al.* [5] and The Europe Economic 2014 [12] that the Europe patent system falls short of addressing fragmentation. The departing point from the previous research presents when the study uses the milestones achieved in the US system to caution the Europe patent on the potential pitfalls and how the system can evade them.

6. Conclusions

Results indicate a subtle loophole in the current US law since it exposes large corporations to multiple patent suits when NPEs target their cash holdings. The primary differences between the two patent systems include disparities in the grace period, the publication of patents, and the application of patent rights. The fragmentation in the European patent system implies that although the EPO awards the patent, it is subject to the laws within the countries that the holder applies.

The findings in this study indicate an urgent need to reduce patent trolling by NPEs through changing the law or transforming the IP marketplace. The patent system in Europe could also require that low-quality patents go through a court that conducts preliminary screening. Additionally, by working towards a more unified approach, Europe can significantly reduce the number of patent trolls [5].

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PERSPECTIVES REGARDING THE IMPACT OF CLIMATE CHANGE ON WORLD ECONOMY

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ABSTRACT

By elaborating this article, we want to analyse the current situation, but also anticipating the actions that will result from climate change and its impact on global economy. Firstly, it is necessary to clarify the terms of specialty, a brief introduction to climate change, but also the presentation of legislative concepts at national, European and international level. Secondly, we shall briefly outline some possible scenarios on global climate change, but also various strategies and policies that can help achieve the expected climate change outcomes. Further, present and future situations will be presented by geographic regions, but also differentiated according to the large economic production flows, and finally, the main effects of climate change on the world economy will be identified.

KEYWORDS: climate change; global economy; legislative concepts; production flows

1. Introduction

Nowadays, large-scale discussions are being held about climate change because they have several repercussions on environment, economy, agriculture, and other sectors of activity. Agriculture is one of the main sectors directly affected by climate change, leading to a reduction in agricultural output, and implicitly, reducing the economy of the country affected by extreme weather phenomena. Adaptation to climate change is `the way to reduce/eliminate the negative effect of climate change on agricultural produce, but also implicitly, on the economy’ [1].

According to the IPCC (2013), the increase in greenhouse gas emissions has contributed to the emergence of climate change caused by man, emissions from the past already determining its size by mid-century and current and future emissions` (i.e. global emissions cuts) which determines the severity of climate change. Also, according to IPCC 2014, adapting to climate change at regional or local level is a field of political involvement, which is of importance for maintaining in good conditions the ecological environments, economic and social situation of a country. The overall objective of this article is to raise awareness of the importance of climate change, as well as highlighting their impact on the global economy [2].

The specific objectives relate to the following aspects, namely: (i) understanding of climate change legislation, (ii) reducing disruptive actions that can lead to accelerating climate change; (iii) presenting present and future scenarios for each study area; (iv) highlighting the impact on geographic regions and production flows. According to the United Nations Framework Convention on Climate Change (UNFCCC) by the adoption of the Paris Climate Change Agreement, the stakeholders consider it necessary to support the implementation of long-term objectives through coordinated and effective action for good sustainable development and the eradication of poverty at national level. So, this agreement seeks to: promote mitigation and adaptation measures; improve the participation of the public and private sector in the implementation of appropriate national solutions; create opportunities for co-ordination between user tools and institutional arrangements [3].

2. Approaches and contributions general on climate change

Factors that influence the current state of the climate act differently across the globe, and for this reason effects and impacts are otherwise different depending on the geographical region. In this respect, it can be seen from previous studies that climate change is happening at a faster pace in the vicinity of the poles compared to other regions around the globe.

The most important natural factors are represented by:

(a) distance from the sea;
(b) ocean currents;
(c) wind direction;
(d) the form of the land;
(e) the distance from the equator;
(f) the phenomenon El Niño.

This phenomenon (El Niño) contributes to the modification of wind and precipitation patterns, it can lead to the occurrence of droughts and floods, especially in the areas adjacent to the Pacific. For example, due to this phenomenon, tornadoes occurred in Florida, smog in Indonesia and forest fires in Brazil. In addition to the natural factors, we must also consider the anthropic ones, because man can influence the climate through his actions. People influence the climate and temperatures by burning fossil fuels, cutting forests, raising livestock and intensifying agriculture. Natural and anthropogenic factors contribute to increasing gas emissions, increasing the greenhouse effect and the global warming phenomenon.

3. National, European and international legislation

At global level, there are the following agreements between the partner states:

• United Nations Framework Convention on Climate Change (UNFCCC). This Convention was established in 1992 with the role of decision-making forum for international action on climate change, and 195 countries have joined this international agreement. Its main purpose is to `achieve ... maintains greenhouse gas concentrations in the atmosphere at a level that prevents dangerous anthropogenic interference with the climate system. Such a level should be achieved within a period enough to allow ecosystems to adapt naturally to climate change, to ensure the necessary food production and to enable sustainable economic development’ [3].

• The Kyoto Protocol

Under the Kyoto Protocol adopted at international level, 37 industrialized countries in the period 2008-2012 to fulfil the criteria for reducing greenhouse gas emissions by an average of 5% over the 1990 limits. Also, the UK has committed to reducing its greenhouse gas emissions by 12.5%. The proposed objective was achieved, and the 37 countries have managed to reduce their greenhouse gas emissions by more than 10%. But there are still countries where greenhouse gas emissions have increased over the period 2008-2012, for example China. This Kyoto Protocol was also agreed for the period 2013-2020, but the signatory countries ratified in a smaller number than the original ones [3].

The Paris Agreement

The UNFCCC has continued negotiations with the states concerned and the result was the adoption of the Paris Agreement in 2015. Significant global effort to reduce greenhouse gas emissions was signed in order to sign this agreement [3].

Thus, 160 UNFCCC stakeholders have committed themselves to reducing their greenhouse gas emissions by 2030, including China, the US and the European Union. The main objective of the Paris Agreement is to avoid raising the global average temperature by more than 2 °C above pre-industrial levels and continuing efforts to limit global warming to 1.5 ° C. The Paris Agreement provides for a review of commitments in 2018 and another review will take place in 2023 and further revisions every five years after this last deadline. In terms of European legislation in the field of climate change, this is represented by the following acts:

• Decision 2016/590 / EU concerning the execution, on behalf of the European Union, of the Paris Agreement adopted under the United Nations Framework Convention on Climate Change;

• Directive 2014/52 / EU amending Directive 2011 / EU refers to the need to assess the impact of climate and climate change vulnerability projects. In this respect, it is considered that the measurement of impacts and risks related to climate change and research into methods of reducing vulnerability is of importance;

• Directive 2003/87/EC of 13 October 2003 (Directive 2003/87) establishes a scheme for GHG emission allowance trading (the Emissions Trading Scheme, ETS) within the Community and amending Council Directive 96/61 establishing the EU scheme for GHGs. The Directive entered into force on 25 October 2003;

• Other implementing provisions refer to Commission Regulation (EC) No. 916/2007 of 31 July 2007 amending Regulation (EC) No. 2216/2004 for a standardised and secured system of registries – pursuant to Directive 2003/87/EC of the European Parliament and of the Council and Decision No. 280/2004/EC of the European Parliament and of the Council; and Commission Decision 2007/589/EC of 18 July 2007 establishing guidelines for the monitoring and reporting of GHG emissions (COM (2007) 3416);

• Decision No. 280/2004 of 11 February 2004 concerns a mechanism for monitoring Community GHG emissions and for implementing the Kyoto Protocol. This Decision establishes a new mechanism for monitoring and reporting GHG emissions to ensure more accurate evaluation and more regular monitoring of the progress made in reducing emissions;

• Decision No. 2005/166 of 10 February 2005 (Decision No. 2005/166) lays down rules implementing Decision No. 280/2004 concerning a mechanism for monitoring Community GHG emissions and for implementing the Kyoto Protocol, as described above, and establishes rules implementing Decision No. 280/2004 as regards to the reporting of information referred to in articles 3(1) and (2) of Decision No. 280/2004, in accordance with article 3 (3) of that Decision;

• Decision No. 2006/944 of 14 December 2006 (Decision No. 2006/944) determines the respective emission levels allocated to the Community and each of its member states under the Kyoto Protocol pursuant to Decision No. 2002/358. The Annex to Decision No. 2006/944 sets out the emission levels in terms of tonnes of CO_2 equivalent allocated to the Community and to member states for the first quantified emission limitation and reduction commitment period under the Kyoto Protocol;

• Decision No. 406/2009 on effort sharing, which came into force on 25 June 2009, sets different (i.e. burden sharing) targets for each member state and provides binding GHG emissions limits for certain categories of emissions that are not subject to the EU ETS for the period 2013 to 2020, to contribute to the EU’s overall 20 per cent cutting GHG emissions objective. Through this measure, stricter GHG emissions cuts may be implemented if an international climate change agreement is reached to succeed the Kyoto Protocol;

• The European Commission has adopted new Environmental and Energy Aid Guidelines, which will be valid from 1 July 2014 until the end of 2020. Notably, it includes new provisions on aid to energy infrastructure to facilitate investment into Smart Grids to promote energy efficiency and cross-border interconnection as it helps to strengthen the internal energy market as well as providing support for system stability and generation adequacy [3].

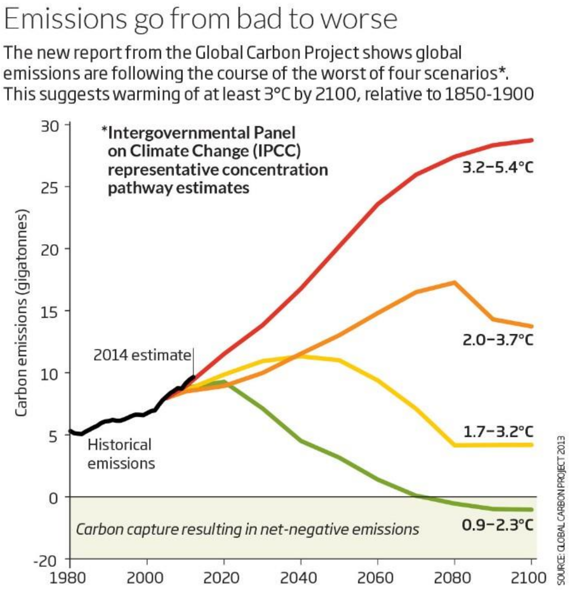
Regarding the national legislation, Romania respects the international and European legislative provisions, but also on the existing national ones, such as:

• Decision no. 1026/2014 for the reorganization of the National Commission on Climate Change. The National Commission on Climate Change is an inter-ministerial body with consultative role, without legal personality, whose activity is coordinated by the central public authority for environmental protection and climate change;

• Decision to approve the National Strategy on Climate Change and Growth based on low carbon emissions for the period 2016-2020 and the National Action Plan for the implementation of the National Strategy on Climate Change and Growth based on low carbon emissions for the period 2016-2020 [4].

4. Possible scenarios on the evolution of global climate change

Climate change does not act the same in all places of the world, causes and consequences are different, and poor economies are more vulnerable to the threat of climate change impacts. In general, climate projections for the next 100 years are wide in scale due to differences in model response and scenario response time, and the difference is given by the model chosen to identify these scenarios. According to the Intergovernmental Panel on Climate Change (IPCC) an increase in global greenhouse gas emissions is expected, indicating an increase in global average temperatures of at least 3 °C to 2100 compared to 1850-1900 [3].


Emissions go from bad to worse

The new report from the Global Carbon Project shows global emissions are following the course of the worst of four scenarios*. This suggests warming of at least 3°C by 2100, relative to 1850-1900

*Intergovernmental Panel on Climate Change (IPCC) representative concentration pathway estimates

SOURCE: GLOBAL CARBON PROJECT 2013

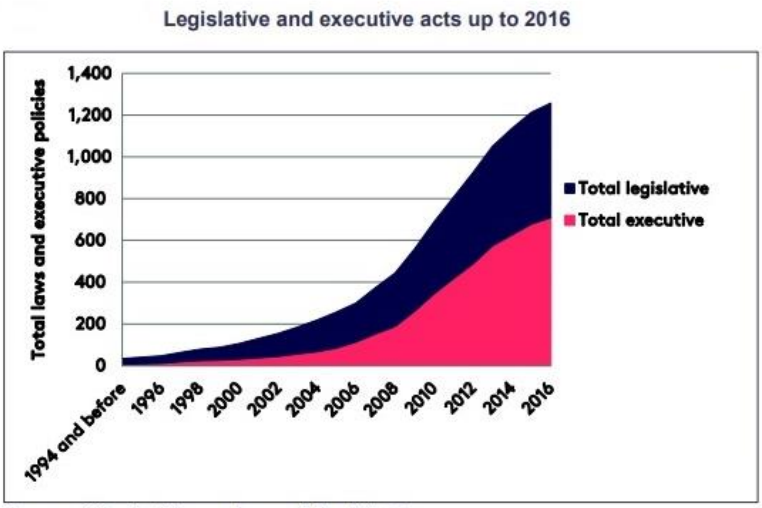
Fig. 1. *Global emissions scenarios* [5]

4.1. Main trends and possible effects

Globally, climate change can have visible effects on the environment, namely through the following actions: melting glaciers, the breakage of ice from rivers and lakes earlier than normal, changing the cycle of plants and animals to adapt to these conditions, the flowering of trees that can occur earlier than usual. In the past, researchers in the field predicted changes that could result from climate change: reducing the amount of ice from the sea, accelerated sea level rise, and heat waves that manifest with a higher intensity. So, the

Intergovernmental Panel on Climate Change (IPCC) indicates that the hypotheses published so far confirm that the net cost of climate change destruction is significant and may increase over time, which could lead to a global economic downturn. Those skilled in the art argue that global average temperatures may increase by up to 1.8 to 5.4 degrees Fahrenheit (approximately 1...3 °C) than those recorded in the 1990 period. Regarding the emergence of the effects of climate change, some NASA specialists state that these are due to the human factor, namely the greenhouse effect that leads to global warming. The greenhouse effect is produced by gases that contribute directly, such as water vapor, carbon dioxide, methane, nitrogen oxide, chlorofluorocarbons (CFCs). The main possible effects that may be due to climate change are:

- sea level rise and ocean acidification, which occur due to increased water molecules when temperatures are higher, significant precipitation and melting glaciers. Increased temperatures lead to the disappearance of coral reefs in the oceans, but also to the occurrence of extreme weather events;
- changes due to rising temperatures will result in higher drought phenomena in some areas of the world, and others will have higher rainfall than usual. Extreme weather events refer to the appearance of very hot summer weather, colder winters than normal, strong storms with electric discharge, but also hurricanes in some geographic areas. Globally, climate models estimate that global warming will cause significant changes in climate models in terms of wind intensity, rainfall and temperature variations;
- melting glaciers, a phenomenon that has long been discussed by researchers in the field. In this regard, it is estimated that the melting of polar ice in the Arctic and Antarctic regions, along with the melting of the glaciers and glaciers in Greenland, North America, South America, Europe and Asia, can lead to the rise of the sea;
- changing fauna and flora as birds migrate from equator to poles due to global warming;
- human communities will be affected by these effects that contribute to the drought phenomenon in certain agricultural areas, snow drop in winter, extreme weather events, changing seasons of vegetation, all of which can produce reduced crop yields and increase fewer animals [2].



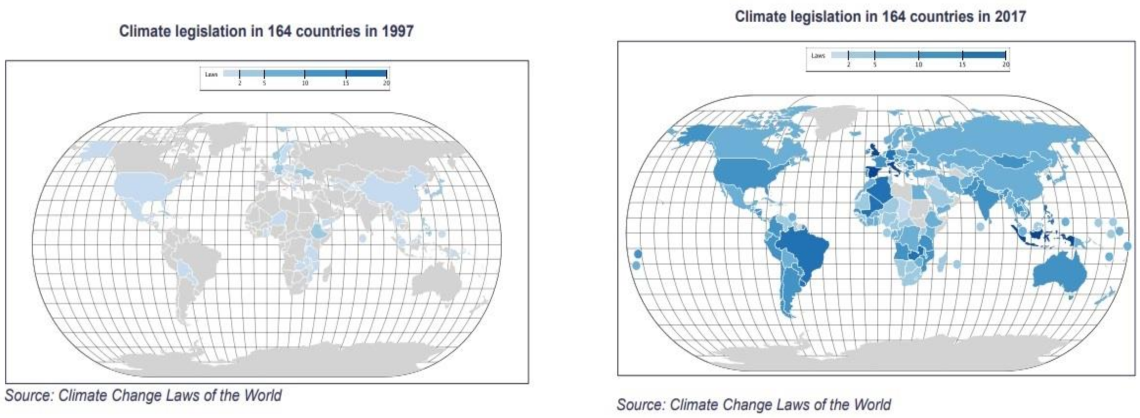
Source: Climate Change Laws of the World

Fig. 2. *Legislative and executive acts up to 2016* [4]

Following the adoption of the Kyoto Protocol, the number of legislative norms on climate change has substantially changed, so at the end of 2016 there were over 1200 laws and policies in the 164 participating states (Figure 2, according to the Global Trends in Climate Change and Law Litigation).

Worldwide, but also Europeans tackle differently climate change, that is why research is done through solutions and legislation implemented in other countries to better manage extreme weather phenomena. Some states rely only on legislative and others focus on the implementation of climate change strategies and plans.

According to the figures above (Figure 3), there is a worldwide increase in the number of law spreads in 2017 compared to 1997, which refers to the importance and awareness of legislative measures on adaptation to climate change, even though the poorest countries in the world do not have the right tools (Guinea, Libya, Somalia, Sudan, etc.).



Climate legislation in 164 countries in 1997

Source: Climate Change Laws of the World

Climate legislation in 164 countries in 2017

Source: Climate Change Laws of the World

Fig. 3. *Climate legislation-comparison between 1997 and 2017* [4]

4.2. Global economy in the context of climate change

According to studies conducted so far, in order to reduce carbon emissions that can lead to the global warming effect, it is necessary to identify ecological and economic solutions that minimize the use of fossil fuels.

Economic experts have analysed cost estimates for achieving the Paris agreement's goal of reducing carbon emissions and maintaining global average temperatures not exceeding 2° and they stated that limiting global actions would require about 1.5% of total income. At the same time, other researchers say the cost could exceed 4% of global income.

Cost-benefit analysis is a commonly used method that provides return on investment in climate change and the results obtained may lead to legislative, but also political support for taking the necessary measures. However, besides the cost-benefit ratio, we must consider the implications of the efficiency and effectiveness of the measures needed to prevent the effects of climate change. In this case, the approaches identified must take account market requirements and propose that the main private sector producers should modify their techniques and current environmental behaviour by using innovative, environmentally friendly and economic tools / technologies. However, the governments and ministries involved have an important role to play in implementing tools and policies to manage present and future situations, taking into account the implications of the activities and processes of companies/companies that can generate carbon emissions into the atmosphere, and thus, to lead to environmental pollution. For example, the instruments that can contribute to reducing greenhouse gas emissions are the application of pollution taxes and transferable/tradable permits.

4.3. The impact of climate change on the global economy

In general, on the long term, it seems that the impact of climate change on the world economy will be a negative one. Global warming could lead to a downturn in the economy, as effects will affect countries' stability due to rising carbon dioxide emissions and global average temperatures. The sector of activity directly affected by climate change is agriculture, as the drought decreases the yield of crops leading to a decrease in food production, then to affect the income of the population. All these effects and many others contribute to higher electricity costs due to high consumption, rising inflation and the phenomenon of mass migration from areas prone to natural disasters (drought, floods) to non-risk areas.

5. Conclusions

In conclusion, global economy will suffer from climate change and this essay was aimed at informing and raising awareness of the public about the effects that can occur and can manifest differently in the world and that is why, it depends on the gravity/intensity/severity of the phenomenon taking into account the geographical area.

The economy can be disturbed by extreme weather events by reducing workforce and productivity, but also of gross capital. In this context, the inflation can increase due to low agricultural output that affects the cost of food and energy consumed for their production. Measures to reduce and mitigate climate change may restrict a state's budget, because they involve additional costs and that is why, it is intended to limit global warming and adaptation to climate change in the early stages so as not to need additional costs after extreme weather events/events. The subject is one that causes widespread discussions, and companies/institutions, together with the governments and ministries involved, must work together to implement strategies/plans, measures and recommendations for adaptation to climate change. An important step is the `Paris Agreement`, which provides limitation of gas emissions in the atmosphere as they lead to global warming. However, a sustainable solution would be that private sector companies could be forced through policies adopted to meet the carbon dioxide removal thresholds and reduce pollution resulting from the activities undertaken. In order to achieve the primary objective of reducing carbon dioxide emissions on a global basis, all institutions involved should have legislative support with collective support.

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