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Energy consumption reduction in recycling processes

Introduction

Concept of energy and effectiveness

Integrated recycling systems development in the environment: design and construction theory; materials – processes and ecological aims of bio-materials and waste technology [*Bieliński and Flizikowski, 2007; Flizikowski, 2011a,b,c; Powierża, 1997; Ministerstwo Gospodarki RP, 2009; Niederliński, 1987; Ziemba, Jarominek and Staniszewski, 1980*].

The selection of a particular type of recycling technical system will depend on a number of factors: throughput, product size and type of material; also, the cost and power requirements, operational costs and environmental restrictions [*Macko, Boniecka and Drop, 2011*]. Therefore, while on the question of pure application, a particular type of machine/system may be an obvious choice, the ultimate decision will probably take into account the peripheral needs and may dictate selection of a different type of machine.

Aim of work

It will not be the purpose of these tutorials to evaluate machine choice on anything other than basic application requirements, as cost factors etc. can vary within short time-scales owing to outside influences. Also, geographical locations may have significant effects on costing, the principles of processing, compression, the impact and principles of screening, recycling and energy systems machinery, monitoring, system control, plant selection and layout.

Recycling and energy systems analysis

The global, environment-functional potential of operation, energy and renovation is analyzed. According to designation, the functional potential of recycling and energy technical systems is the whole of its external operating possibility [*Sienkiewicz, 1987*]*:*

- human potential $P^L(t)$,
- technical potential $P^T(t)$,
- energy – material potential $P^E(t)$,
- controlling potentia $P^S(t)$.

Function of operating potential:

$$P_d(t) = \Phi[P^L(t), P^T(t), P^E(t), P^S(t)] \tag{1}$$

and especially:

$$P_d(t) = \pi_d(t) M_d(t) \varepsilon \tag{2}$$

Operating (material or/and energy) potential equation in the period $[t_0, T]$:

$$P_d(t) = P_d(t_o) - \int_{t_o}^{T} p_d^E(t)dt - \int_{t_o}^{T} p_d^s(t)dt + \int_{t_o}^{T} p_d^o(t)dt \tag{3}$$

where:

$P_d(t_o)$ – initial energy-material operating potential of global acting or only: bio-material, polymer- and fiber-waste or water waste, willows, oil plants, corn straw, flowing rivers, wind, sun rays, hydrogen, magneto hydrodynamics, farm bio-gas, heat pumps, oceans or the Baltic Sea, fuel cell coal and nuclear energy,

$p_d^E(t)$ – density of effectively used stream of energy-material potential,

$p_d^s(t)$ – density of lost stream of energy-material potential,

$p_d^o(t)$ – density of recovered (recycled or obtained from the environment) stream of energy-material potential.

Each of the potentials of any recycling operations in the environment, as well as the environment for machines, are described by reliability-that is by the function taking into account its active and passive value, quality, which is the distance of practical effects from the pattern of theoretical possibilities.

Human potential

The reliability of human potential is defined with the following indices [*Flizikowski, 2011a*]:

1. Number L^L of people appointed to recycling operation,
2. Number $M^L(t)$ of people taking part in recycling operation,
3. The theoretical ε^L human possibilities,
4. The real $\pi^L(t)$ creative possibilities and the level of human responsibility.

For one active employee the index of reliability amounts to:

$$N^L(t) = \frac{\pi^L(t)}{\varepsilon^L} \tag{4}$$

The value of the theoretical, developmental, and creative possibilities index and the reliable operation of an employee (employees) tends to one, if:

- the undoubted motivations occur, $\varepsilon_m^L = 1$
- the full knowledge occurs (know-how, ecological and synergic), $\varepsilon_w^L = 1$
- the free access to the canal occurs, $\varepsilon_k^L = 1$
- the adequate to production level of needs and growing markets occur. $\varepsilon_r^L = 1$ and

$$\varepsilon^L = \varepsilon_m^L \varepsilon_w^L \varepsilon_k^L \varepsilon_r^L \Rightarrow 1 \tag{5}$$

The most often one accepts the value of the criteria realization $0.50 < \pi^L \le 1$, criteria non-realization $\pi^L \le 0.50$.

Technology potential

With a booming wind, bio-mass and a more renewable energy industry, the question is now arising of how to deal with end-of-life plastics, fibers and bio-material units [*Tomporowski. 2011*], elements, turbines, and particularly the blades made of hard – to – recycle composites. This investigates possible routes for the recycling of wind turbine blades.

The global renewable energy and particularly the wind industry are growing fast, in terms of both the number of turbines and their sizes. Wind turbine blades typically consist of reinforcement fibers, such as glass-fibers or carbon-fibers; a plastic polymer, such as polyester or epoxy; sandwich core materials, PET or balsa wood; and bonded joints, coating (polyurethane), and lightning conductors. At the moment, there are three possible routes for dismantled units, elements, installations of renewable energy, particularly wind turbine blades: landfill, incineration or recycling.

The operation and regeneration reliability of technical potential is defined out of the relation:

$$N^T(t) = \frac{T^T}{M^T(t)} \frac{\pi(t)}{\varepsilon^T} \tag{6}$$

The index of theoretical possibilities of reliable techniques of operation tends to one, if:

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– the construction with its substantial scope includes also the destruction, $\varepsilon_k^T = 1$,
– the building, machine are constructed according to the construction, $\varepsilon_p^T = 1$,
– use, operation, resistance, and durability are adequate, $\varepsilon_e^T = 1$, and

$$\varepsilon^T = \varepsilon_k \varepsilon_p^T \varepsilon_e^T \Rightarrow 1 \qquad (7)$$

The real possibilities of operation and regeneration are measurable. Already known from literature are the values of the construction indices, products, and materials quality, the mathematical descriptions of operational states, and recirculation properties.

Energy – material potential

The reliability of the energy and material potential operation is characterized by the indices [*Flizikowski, 2011a;, Popczyk, 2010*]:
– the amount of provided, useful energy and matter, E^E,
– the amount of the used energy and material carriers, $M^E(t)$,
– theoretical energy and material possibilities, ε^E,
– real and useful energy and material possibilities, $\pi^E(t)$.

The value of the reliability index of the potential (sources) usage of energy and matter tends to one, if:
– the energy of renewable sources is used (solar, wind, water, bio-gas, hydrogen cell, etc. *(URE, (2011)*), ($\varepsilon_q^E = 1$)
– the processing is realized in order to meet the needs of hunger and thirst, ($\varepsilon_l^E = 1$),
– the processing is realized in the proper time, ($\varepsilon_p^E = 1$),
– the highest level of the safety process is being provided, ($\varepsilon_s^E = 1$),
– the energy and material waste are limited to the rational minimum, ($\varepsilon_u^E = 1$), and then:

$$\varepsilon^E = \varepsilon_q^E \varepsilon_l^E \varepsilon_p^E \varepsilon_s^E \varepsilon_u^E \Rightarrow 1 \qquad (8)$$

The energetic aspect of recycling processing reliability seems to be especially attractive if the facts that each processed material also possesses the energetic potential have been taken into account, and is material [*Ustawa Sejmu RP, 2011*].

Controlling and monitoring potential

Reliability of controlling potential. The following ones belong to indicators describing the controlling potential (the description is limited to controlling potential exclusively, as the basic concept tool of the grinders' designer's activity) [*Sienkiewicz, 1987; Flizikowski, 2011a*]:
– possible volume S^S of controlling information,
– volume of information $M^S(t)$ used actively and usefully,
– theoretical possibilities ε^S and decision-informative needs,
– temporary course of real $\pi^S(t)$ executive possibilities.

Theoretical information possibilities assume the value equal to one, if [*Flizikowski, 2011a,b,c*]:
– information ensures realisation of the process in the autonomous, reliable, solid and integral mode ($\varepsilon_a^S = 1$),
– controlling system automatically eliminates negative after-effects of processing, ($\varepsilon_e^S = 1$),
– controlling system is adopted for self-diagnosing and operating in the defined, efficient tolerance zone ($\varepsilon_{d-d}^S = 1$)

$$\varepsilon^E = \varepsilon_a^S \varepsilon_e^S \varepsilon_{d-d}^S \Rightarrow 1 \qquad (9)$$

Conclusions

As it was said in the introduction, the whole idea of recycling is based on three demands:
– to minimize plastic, fibers and bio-material waste as much as possible;
– to minimize the amount of energy (resources) consumption; and
– to keep the production level as high as possible.

On the basis of the performed recycling and energy systems modeling in the direction of the objectiveness of operating efficiency measurements and renewal of technical systems, together with their environment (surrounding), observations and conclusions of practical meaning may be drawn up:
1. The problem of ecological energy reliability – operating, renewal and processing, concerns a system and its surroundings, may be solved on the basis of analysis of the factors describing the environment, human, technical, energy – matter and controlling potential.
2. The risk measure of unfavorable recycling effects accompanying the operation and reaching the working target is the reliability index and the index of needs of creative work, and renovation, recovery and restoration of potentials plays a tremendous innovative and strategic role in designing environmental power processes.

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This work was financially supported by the Polish National Centre for Research and Development in 2010-2013.