USING RENEWABLE SOURCES IN THE PULP AND PAPER MILLS

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The pulp and paper industry is a major consumer of natural sources (wood) and energy (fossil fuels, electricity) and a significant contributor of pollutant discharges to the environment. In this paper there are presented pulp and paper making process and steam and power generation using renewable sources. This paper includes also an exergy analysis of the steam and power generation process for a pulp and paper mill. Based on the analysis, two sustainability indicators were calculated: the exergetic efficiency and the exergy renewability.

Keywords: black liquor, bark, exergy efficiency

1. Introduction

Conventional energy sources based on oil, coal, and natural gas have proven to be highly effective drivers of economic progress, but renewable energy sources such as biomass, wind, solar, hydropower, and geothermal can provide sustainable energy services.

The use of renewable energy is expected to increase significantly motivated by the need to reduce fossil-fuel related CO2 emissions that contribute to the greenhouse effect, as well as by the decreasing reserves of these fossil fuels. Biomass will be the most important source of renewable energy as it is not only suitable as fuel for electricity generation, but it is also the only source of renewable carbon.

For pulp and paper industry the main raw material is a renewable resource (wood). From the technological process results two sources of biomass: black liquor and bark. These renewable sources usually are burnt to recover chemicals and energy. *Black liquor* is a residue from the chemical pulping process. The combustible substance is mainly lignin. The *bark* results from debarking process.

The exergy is a measure of potential harm from production and consumption material wastes which are disposed into the environment. This exergy is dissipated into the environment, and through its chemical potential can cause harm to the environment and living cells. From this reason, two indicators derived from exergy analysis were used to evaluate energy resources conversion and environmental performance: exergy efficiency and exergy renewability, [1].

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2. Pulp and paper making process

Pulp and paper mills are highly complex and integrate many different process areas including wood preparation, pulping, chemical recovery, bleaching, and papermaking to convert wood to the final product (see figure 1), [2].

Wood preparation involves mechanically removing the bark from logs and breaking down the debarked logs into wood chips.

Pulping is the method used to convert fibrous material such as wood into slurry of fibers. Processes can be classified as chemical and mechanical. Chemical processes remove the most lignin, a component of wood that holds the fibers together and adds strength and stiffness to trees, but results in weaker paper that yellows with age. Mechanical processes do not remove any lignin.

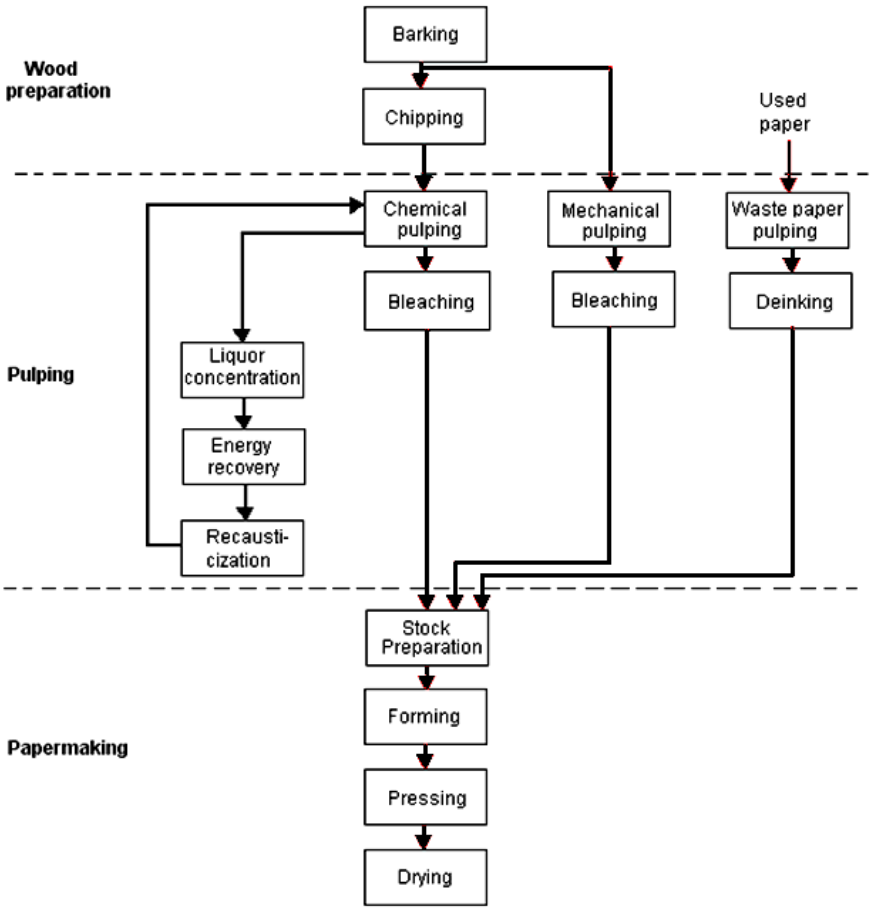

Fig.1. Major paper manufacturing processes

Chemical recovery enables the recovery and reuse of chemicals used in chemical pulping. During the recovery process, steam and electricity are generated from the organic material remaining in the slurry after the pulp has been separated out.

Bleaching is a chemical process used to whiten or brighten pulp before it is used in papermaking. Mechanical pulps contain a significant portion of original lignin and are whitened by decolorizing the lignin (a nonpermanent effect). In chemical pulp, bleaching removes the small amount of remaining lignin for a more permanent change in pulp brightness.

Papermaking involves four main stages: preparation of homogeneous pulp slurry, forming, pressing and drying.

3. Steam and power generation using renewable sources

The pulp and paper industry is energy-intensive, requiring large amounts of steam and electricity to process wood into paper and paper products. The papermaking process is the most energy intensive and consumes about 45% of total energy use. Drying is the highest energy consumer, requiring large amounts of heat (steam) to evaporate water from paper or paperboard, [3]. Pulping is the next largest consumer of energy.

Pulp and paper mills also utilize significant amounts of self-generated fuels that are byproducts of wood processing such as bark and spent pulping liquor. These are *renewable sources*. On average, more than 40% of electricity is produced onsite along with cogeneration of steam.

Three main types of boilers are used in the paper industry: the *recovery boiler*, which recovers chemicals and energy from spent kraft cooking chemicals, the *bark boiler* which recovers energy from bark and wood wastes, and the *power*

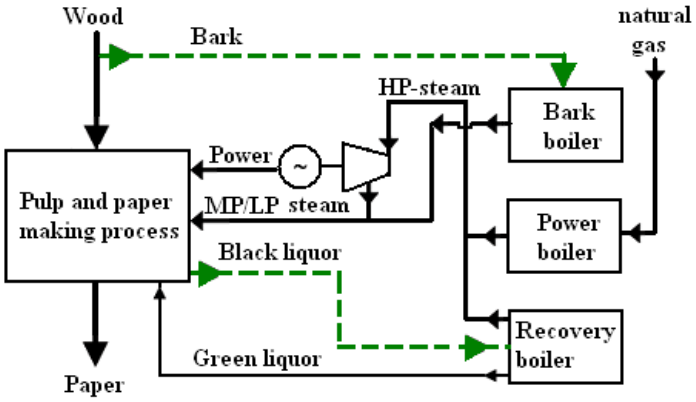

Fig. 2. Simplified block diagram of a pulp and paper mill showing renewable sources

boiler, which generates heat using a variety of fuels.

Figure 2 shows the simplified block flow diagram of pulp and paper mill with renewable resources: bark and black liquor. High-pressure (HP) steam, generated by the power boiler and recovery boiler, is sent to back-pressure steam turbines to generate electricity, with moderate (15 bar) or low (4 bar) pressure (MP/LP) steam used for direct or indirect process applications. MP/LP steam is also generated by the bark boiler.

4. Exergy evaluation of the steam and power generation

The exergy evaluation of the steam and power generation was realized for an integrated pulp and paper mill which has the simplified block diagram in figure 2. The analysis was made for a year period. The exergy flows were calculated using standard method, [4]. For the exergetic calculus were considered the following surrounding conditions: pressure, p_0=101.3 kPa, and temperature, t_0=20^0C.

Results of exergy analysis are shown in the table 1.

Table 1

Results of exergy analysis

Exergy flow	Values, [TJ]
Input(consumed) with:	3845
- Natural gas	1832
- Black liguor	1776
- Bark	237
Output (useful) with:	833
- MP/LP steam	617
- Power	216
Destroyd and lost	3012

With the information generated by this exergy analysis, two indicators for to quantify the sustainability of the power productions were calculated: *exergy efficiency* (ε), which shows how well the energy quality is preserved in the system and *exergy renewability*, (α), which considers the consumed exergy of renewable resources compared to the total of all consumed exergy. These indicators are calculated as:

$$\varepsilon = \frac{E_u}{E_c} \tag{1}$$

$$\alpha = \frac{E_{c,renewable}}{E_c} \tag{2}$$

where: E_u is useful exergy, E_c – chemical exergy of consumed fuel in the steam boilers and $E_{c,renewable}$ – exergy consumed from renewable sources, bark and black liquor, in this case.

Values of these indicators are shown in the table 2.

Table 2

Values of exergy indicators

Indices	Value, [%]
Exergy efficiency	0.22
Exergy renewability	0.52

Note, exergy renewable is better than exergy efficiency. The high value of the exergy renewable is due mainly to using of black liquor. The low value of exergy efficiency is due to low steam temperature demanded for the technological process. The useful exergy could be more if steam flow generated of bark boiler should pass through steam turbine, because power is exergy.

Using of renewable sources brings about fuel saving and reduction CO_2 emissions. The fuel saving is about of 68 715 tcc per year or 59 700 000 Nm^3 natural gas. CO_2 emissions reduction, calculated for natural gas, [4], corresponding to emission factor 55.5 tCO_2/TJ, is of 111 722 tCO_2 per year.

5. Conclusions

The use of the renewable sources leads to the fossil fuel saving and reduction of the greenhouse gases and pollutant emissions.

Pulp and paper mills are heat and power self-sufficient by using the heat value of the thick liquor, bark and wood waste. Today, black liquor is combusted in recovery boilers and bark is combusted in bark boilers. In existing systems, both technologies result in rather low electrical efficiencies. There are alternative technologies, such as gasification, that offer more efficient conversion of the organic materials in black liquor to energy and other products.

This paper includes an exergy analysis of the steam and power generation process for a pulp and paper mill. Based on the analysis, two sustainability indicators were calculated: the exergetic efficiency and the exergy renewability. It were also calculated fuel saving and, corresponding methodology EEA/EMEP/CORINAIR, CO_2 emission reduction. The estimated economical saving shall be about 12 328 000 Euro per year.

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