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Analysis of sawmill waste charring in the steel retorts

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Abstract: *Analysis of sawmill waste charring process in the steel retorts.* There is described the process of sawmill waste charring in the steel retorts that belong to the contractor operating in Forest Inspectorate Kozienice. The process consists of nine stages and lasts over 76 hours, including 14 h (19%) of the effective charring, 47 h (62%) of cooling the retorts, and the remaining 15 h for cleaning, loading and unloading of the retort. The economic analysis for the assumed data showed that average specific cost of obtaining a 2.5-kg bag of charcoal made of sawmill waste was equal to about 5 PLN, while the limit profitability point, calculated for the process with the use of a new retort, amounted to 87 bags of charcoal, and with the depreciated retort – 67 bags.

Key words: pyrolysis, charcoal, retort.

INTRODUCTION

The pyrolysis, i.e. thermal wood decomposition (destructive wood distillation) is the process of subjecting wood to the action of thermal energy with the limited access to air. The course of thermal decomposition of wood and its particular components is greatly affected by process conditions: temperature, heating time and environment.

Considering temperature inside the retort one can distinguish four phases of thermal wood decomposition process. During heating of wood, the water is released at the temperature of 170ºC, then at temperature about 170–270ºC there are released the combustible and incombustible gases: carbon monoxide (CO), carbon dioxide (CO_2) and small amounts of methanol and acetic acid. The tar releasing starts at the same time. The exothermic wood decomposition starts at temperature 170–180ºC and proceeds automatically to about 400ºC, while the coal annealing in order to remove the volatile substances occurs at temperature 400–500ºC.

The charcoal calorific value amounts on the average to 29.1 MJ/kg (21.2 MJ/kg for pine wood and 20.1 MJ/kg for beech wood). The kind of wood used in burning is important in evaluation of coal colorific value. The hardwood yields better charcoal than the softwood. The charcoal quality is also affected by wood faults, first of all by decay. When wood raw material is subjected to decomposition caused by bacteria, its output is greatly decreased.

Good charcoal is characterized by black colour with blue shade and lustre. It has a porous structure, low density (up to 250 kg/m^3) and high adsorption ability. It burns without smoke.

In the market one can distinguish the generator charcoal charred at temperature up to 400ºC, that contains 10–20%

of volatile particles, and the annealed charcoal obtained by annealing at temperature 750–850ºC, that contains up to 4% of volatile particles [Laurow 1996a, b; 2003].

Coal is used in many fields of industry, most often as an absorbent in gas or water filters, as fuel for grills or the component of gun powder. In pharmaceutical industry it is used in production of tablets against indigestion and digestion disorder, in food industry it is used as a dye in the concentrated fruit juices or jams.

Historically, production of wood charcoal dates back to the first century of A.D., however, it is bound up with development of metallurgy in modern times. At the beginning, charcoal was produced in primitive kilns, that were used still at the end of seventies of twentieth century, then in the retorts.

Number of enterprises dealing with charcoal production decreases in our country from year to year. In 2000, in 14 forest inspectorates situated in Bieszczady, Beskid Niski and Pogórze, this production was carried out in 43 enterprises; their owners held in total 467 retorts. In 2008 the number of retorts decreased to 248 [Kusiak, Marszałek 2009]. At present, the number of working retorts is not known; it is estimated that it amounts to half of retorts recorded four years ago.

In recent years, charcoal from Ukraine and Russia is imported to Poland; although its quality is worse than the Polish one, but it is cheaper. Therefore, the question arises: what is the real cost of charcoal production under Polish conditions?

This work aimed at describing the process of charcoal charring from sawmill waste, carried out by Polish contractor, and at estimation of the constant and variable production costs and profits, with the use of a new one and depreciated retort.

MATERIAL AND METHODS

The process of charcoal charring was investigated in the private firm in Forest Inspectorate Kozienice, Forest District Januszno.

The investigations were carried out in three retorts of RPW – 000 type, during making charcoal of birch sawmill waste. The basic structural elements of the retort are presented in Figure 1.

The retort consists of a roll of thick metal sheet, of diameter about 2.6 m and height about 2.5 m. Figure 2 presents the site of 0.35 ha, where the retorts were accommodated.

The times of particular stages of charcoal charring were measured and summed up according to equation:

$$t_c = t_1 + t_2 + \ldots + t_n$$

FI URE 1. Open retort used on charring site: 1 – fire opening, 2 – loading door, 3 – internal jacket, 4 – e ternal jacket, 5 – air opening, 6 – chimneys

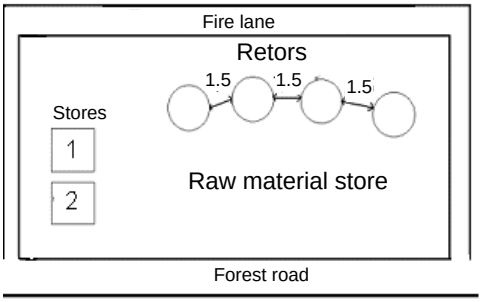

FIGURE 2. Layout of working site

The time measurements were executed with the use of a stop watch, with accuracy dependent on duration of a given stage. The results of stages below 30 min were rounded-off to 0.5 min, that above 30 min – to 1 min.

In calculations of constant and variable costs, incomes and profits there were used the commonly known equations [Milewski, Kwiatkowski 2005].

SPECIFICATION OF WOOD SUBJECTED TO CARBONIZATION

In the investigated three charring processes, there were used the birch sawmill wastes in the form of thin slates of average width above 30 mm and length above 2 m. Following its transportation from a sawmill, the raw material was stored on a yard in front of the retorts. Prior to loading to retorts, it was cut into smaller pieces with the use of internal combustion chain saw.

ANALYSIS OF CHARCOAL CHARRING PROCESS COURSE

The operations of charcoal charring were performed manually, usually by two workers by one retort. There were distinguished ten process stages in charcoal production: cleaning of retort (t_1), placing of floor and light-wood (t_2), material preparation and loading of retort (t_3), firing of wood (t_4), charcoal charring – first phase (t_5), charcoal charring – second phase (t_6), cooling of retort (t_7), opening of retort and cooling of charcoal (t_8), unloading of charcoal (t_9).

The first stage of charcoal charring is cleaning of retort that follows the previous process, with the use of simple tools. The worker removes small pieces of charcoal and ash. Then, he cleans the fire openings and chimneys, removing the coke and tar remained inside.

The subsequent stage is placing of „floor". It consists of 6 steel star-arranged pipes. The light-wood of small pieces is placed between them and poured with a fuel. On so prepared surface there is placed the material for charring (Fig. 3).

Preparation of material for charring takes place simultaneously with loading of the retort, which is entirely filled with wood. To prevent the small sawmill waste pieces from falling outside, the retort door is blocked with thicker assortments of the sawn timber (Fig. 4). After closing door, the retort loading is finished through fire opening with small pieces of wood.

When the retort is completely filled with wood, a burning torch is introduced through bottom opening to fire the light--wood. After few minutes, when a dense smoke starts to get out of the retort, the door should be tightly closed (and partially fire openings also) to limit inflow of oxygen. This starts the first process stage, during which a dense white smoke gets out from the chimneys. During this stage the workers gradually cover up air openings with sand to control the oxygen inflow; too much oxygen can disturb

FIGURE 3. Floor with light-wood placed inside retort

FIGURE 4. Retort fully loaded with sawmill wastes

the process and cause burning wood to a cinder.

The second process phase starts, when smoke getting out of chimneys becomes less dense and light-blue. Majority of retort's openings are already closed; the workers supervise and control the charring process by temperature measurements of external retort jacket. Upon completion of the second charring phase, chimneys are removed and fire opening is tightly closed to cut off oxygen inflow to the retort; then, it is distinguished. When the retort is cooled, workers open the door and leave it open for several hours, to let out the remaining carbon monoxide and to decrease charcoal temperature. The obtained charcoal fills the retort in 1/4 of its volume.

Upon cooling charcoal, it is unloaded manually from the retort, at the beginning into a wheel-barrow, and then into paper bags of 2.5 kg each. Wood pieces that remain at retort bottom are screened; bigger pieces are put into bags, and smaller ones are utilized.

The bags filled with charcoal are sewn and placed in stores or directly collected by customers from the site. In consideration of small storage area, the contractor does not burns charcoal for the future; he collects orders and produces charcoal accordingly.

TABLE 1. Results of time measurements for particular stages

Stage		Duration of stages in retorts [h]			Mean [h]	[%]
		first	second	third		
Cleaning of retort (t_1)		0.33	0.33	0.33	0.33	0.43
Placing of floor and light-wood (t_2)		0.42	0.33	0.33	0.36	0.47
Preparation of material and loading of retort (t_3)		6.00	7.00	6.33	6.44	8.43
Firing of wood (t_4)		0.25	0.33	0.33	0.31	0.41
Charcoal charring	first phase (t_5)	7.25	7.00	7.67	7.31	9.57
	second phase (t_6)	7.00	7.00	7.33	7.11	9.31
Cooling of retort (t_7)		47.50	45.00	49.00	47.17	61.77
Opening of retort and cooling charcoal (t_8)		1.00	1.00	1.50	1.17	1.53
Unloading of charcoal (t_9)		6.00	6.00	6.50	6.17	8.08
Total cycle (t_c)		75.75	74.00	79.33	76.36	100

Results of time measurements for particular stages in the three investigated retorts are presented in Table 1.

It is evident from Table, that cooling of the retort is the longest stage in entire process; it lasts over 60% of time, while charcoal charring itself lasts only 19% of entire process (the first and second phases together).

In every retort 10 m^3p of wood were placed. The factor for conversion stere meters into cubic meters was assumed as 0.45, thus volume of wood was equal to 4.5 m^3. Moisture content of birch waste used in charring was equal to about 25%. In calculations of wood mass there was assumed the wood density as 650 kg/ m^3, that gave 2925 kg. On the average, 730 kg of charcoal were obtained from a single retort.

COSTS AND PROFITS OF CHARCOAL PRODUCTION

The production costs and profits were analyzed for the contractor that owned the depreciated retorts (used for over 10 years) and the new ones. Current price of a new retort amounts to 27 500 PLN. The following data were assumed in calculations: number of retorts – 4, time – 12 months, number of cycles per month – 8, depreciation – 7.0%, number of workers – 2, workers' salary – 11 PLN/h, land tenure cost per month – 246.00 PLN, volume of wood in single retort – 10 m^3p, price of material – 70 PLN/ m^3p, price of empty bag – 1.50 PLN/pcs, price of bag filled with charcoal – 10 PLN/pcs (producer's data), tax – 18.0%, average number of bags from single retort – 292 pcs.

The constant, variable and total costs are presented in Table 2 for the new and depreciated retort.

Average specific costs for purchasing the new and depreciated retort amount to 5.30 PLN/pcs and 5.03 PLN/pcs, respectively.

Average income, gross profit and net profit (after tax of 18%) and specific profit for the new and depreciated retort are presented in Table 3.

The profitability threshold under the determined conditions will be reached, when minimum 87 bags are produced

TABLE 2. Constant, variable and total costs for the new and depreciated retort [Jankun 2012]

Retort	Costs [PLN]							
	Depreciation	Work	Tenure	Material	Package	Constant	Variable	Total
	K_a	K_p	K_d	K_m	K_o	K_s	K_z	K_c
New	80.21	299.42	30.75	700.00	438.00	410.38	1 138.00	1 548.38
Depreciated	0.00	299.42	30.75	700.00	438.00	330.17	1 138.00	1 468.17

TABLE 3. Income, total and specific profit for new and depreciated retort [Jankun 2012]

Retort	Income	Profit [PLN]		
		Gross	Net	Specific
	R	Z_b	Z_n	z_j
New	2920.00	1 371.62	1 124.73	3.85
Depreciated	2920.00	1 451.83	1 190.50	4.08

with the new purchased retort; the respective value for utilization of the depreciated retort amounts to 67 bags.

SUMMARY AND CONCLUSIONS

Charring of charcoal in the steel retorts is a process that needs no advanced technologies. Majority of operations are executed manually or with the use of simple equipment and tools.

- In the process there were distinguished nine stages; however, precise determination of duration of the first and second phases was difficult, since the smoke coming out from the retort chimneys was gradually changing its colour.

A single process of making charcoal lasts on the average 76.36 h, including effective charring – 14.41 h (about 19%), and cooling 47.17 h (about 62%).

- In a single retort, 10 m^3p of birch sawmill waste (about 2925 kg of wood) yield about 730 kg of charcoal; it is about 25% of raw material input.
- Average costs per new retort amount to 1548.38 PLN, while per appreciated retort to 1468.17 PLN. The income is equal to 2920 PLN in both cases, and the profit to 1124.73 PLN (new retort) and 1190.50 PLN (depreciated retort).
- The analysis of costs and profits proved that charring of charcoal is profitable, also for the contractors planning to purchase the new retorts.

REFERENCES

JANKUN A. 2012: Analiza procesu wypalania węgla drzewnego w stalowych retortach, praca magisterska w Katedrze Maszyn Rolniczych i Leśnych, Wydział Inżynierii Produkcji, 63 s.

KUSIAK W., MARSZAŁEK E. 2009: Wypał węgla drzewnego w Bieszczadach Drwal nr 7–8/2009, s. 30–31.

LAUROW Z. 1996a: Węgiel drzewny z retort stalowych Prz. Tech. Rol. i Leś., nr 11, p. 21–23.

LAUROW Z. 1996b: Wpływ zwęglania drewna w retortach stalowych na środowisko przyrodnicze Prz. Tech. Rol. i Leś., nr 12, p. 20–21, 23.

LAUROW Z. 2003: Produkcja węgla drzewnego w warunkach polowych. Prz. Drzew., nr 6, p. 11–17.

MILEWSKI R., KWIATKOWSKI E. 2005: Podstawy Ekonomii, Wydawnictwo PWN, wyd. III zmienione, Warszawa, p. 130–135.

Streszczenie: *Analiza procesu wypalania węgla drzewnego z odpadów tartacznych w stalowych retortach.* W artykule opisano proces wypalania węgla drzewnego z odpadów tartacznych brzozowych w stalowych retortach oraz oszacowano koszty związane z jego wypałem. Badania prowadzono na terenie wypalarni znajdującej się na obszarze należącym do Nadleśnictwa Kozienice. Proces wypalania prowadzono w trzech retortach. Całkowity czas trwania każdego procesu wynosił ponad 76 godzin. Składał się z dziewięciu etapów: oczyszczania retorty, ułożenia podłogi i podpałki, przygotowania materiału i załadunek retorty, podpalenia drewna, wypału węgla – pierwsza i druga faza, studzenia retorty i węgla oraz jego wyładunek. Przy czym wypalanie trwało 14 h (19%), studzenie retorty 47 h (62%), a pozostałe etapy łącznie 15 h. Analiza ekonomiczna wykazała, że średni koszt jednostkowy pozyskania 2,5-kilogramowego worka węgla drzewnego wynosi ponad 5 złotych, a graniczny punkt rentowności wyliczony dla procesu przy zastosowaniu nowej retorty to 87, a zamortyzowanej – 67 worków węgla.

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