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SOLAR ENERGY EXPLOITATION AT SAWN WOOD DRYING PROCESS WITHIN SLOVAKIA

Richard Bergel, Jozef Víglaský, Marian Ježo
Technical University in Zvolen, Faculty of Environmental and Manufacturing Technology, Department of Environmental and Forest Technology
Zvolen, Slovakia

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ABSTRACT

Nowadays, the various installations of solar sawn wood drying kilns exist there. There are systems with an opened cycle of a drying process and direct solar energy exploitation. These drying kilns are suitable for utilization in the tropical and temperate oceanic climatic zones. Within the temperate continental climatic zone the solar drying kilns with a closed cycle of drying process and an external solar collector are offered as a more recognised solution. This paper deals with the solar energy exploitation at these types of drying kilns. The possible solar energy exploitation at the beech and spruce sawn wood drying in a low-capacity drying kiln within the region with the continental climatic zone is confirmed by T*Sol Expert 4.5 simulation software.

KEYWORDS: Sawn wood; sawn wood drying kiln; solar energy; solar collector; solar sawn wood drying kiln.

INTRODUCTION

The Sun can be considered as a main resource of life on the Earth. Resource of solar energy are thermonuclear processes running inside its at high temperatures and pressures. The Sun is considered as a large thermonuclear reactor which works continually and itself is ideally regulated. The energy which is released at the fusion is continuously being sent out from the sun surface which is called the photosphere into space as a radiation with the similar spectral composition as a black solid body with temperature of 5800 K. From the energy point of view, it is important to know a value of the solar radiation intensity on the earth atmosphere border which is called the solar constant. This constant (Io) gives the energy flow which is sent by the Sun on the earth surface of 1 m^2 in average, perpendicularly reversed to the sun rays at the average distance of the Earth from the Sun $1.49597870.10^{11}$ m in disregard of absorption and dispersion (Sen 2008; Libra and Poulek 2010). Regarding to elliptic trajectory of the Earth, the value of the solar constant is moving in interval from 1365.0 to 1367.2 $W.m^{-2}$ and on the basis of an agreement, the average solar constant value was defined as Io = 1366 $W.m^{-2}$ (Foster at al. 2009).

Wood as a product of the photosynthesis, on whose production the solar energy participates, was, is and probably will be one of the most used materials in a construction industry, furniture industry and other branches. However, the wood of a freshly felled tree contains a significant amount of water – mainly free water, which is the main reason for fungal attack, low strength and high weight. These failures are being removed by a drying process. Wood can be dimensionally stabilized and there is a possibility to increase of stiffness, strength, hardness and to decrease of weight by lowering moisture content - during the drying process.

By Pirasteh et al. (2014), energy used for drying lumber is 40-70 % of the total energy used in the processing of raw wood on the sawn wood of the desired moisture content. This well known high energy requirement of sawn wood drying technological process and the strongly decreasing state trend of world resources of the energy conventional raw materials are the critical factors which forces us to look for new, if possible renewable forms of energy, where the emphasis is given on their environmental acceptability.

The solar collectors' application for sawn wood dryer which can decrease the financial costs on total sawn wood drying and environmental impacts from the conventional energy carrier utilization can be qualified as one of the attractive projects.

This paper gives an insight on the solar energy utilization possibilities at the processes of sawn wood drying within the temperate continental climatic zone.

MATERIAL AND METHODS

Motivation

Many researchers and constructors all over the world have dealt with the issues of the solar drying and solar dryers. Within period of the 60's – 90's of the 20th century many experimental solar sawn wood dryers were researched and built. The research works of some authors, for instance Wengert and Oliveira (1987), Alvarez and Fernández (1990), Chen and Helmer (1984) give a data about direct and indirect, passive and active solar sawn wood dryers which utilize the solar air collectors for the solar energy storage. Also, the attention dedication of this issue exists today. Luna et al. (2009), describe the solar sawn wood dryers through capturing and utilizing of the solar energy via the air and water solar collectors collaboration. Helwa et al. 2006 created and evaluated an efficiency of direct solar sawn wood dryer model. Studies which deal with the mathematical models of the solar sawn wood dryers and their optimizations are appearing still more (Bekkioui et al. 2009; Khater et al. 2004).

The mentioned studies describe the devices which are suitable actually for sawn wood drying within the tropical and temperate oceanic climatic zones with lower differences of day and night temperatures.

Solar dryers of sawn wood within temperate continental climatic zone

Among countries of temperate continental climatic zone is as well possible to include also the Slovak Republic. With regard to exploitation of solar energy by means of solar collectors, it is not significant difference among eight regions of Slovakia. Difference among „the purest"and „the most abundant" regions with regard to quantity of solar energy is approx. 15 %. On the Fig. 1, we can see quantity of impinging global solar radiation on horizontal area and on are with angle of 35° within the vicinity of Zvolen.

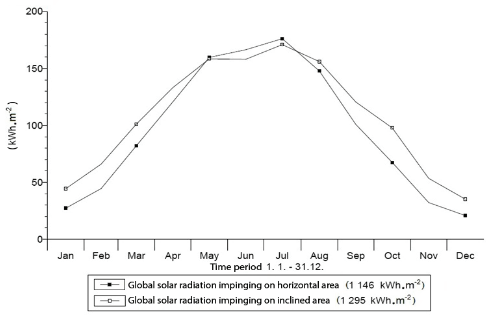

Fig. 1: Impinging global solar radiation on horizontal plane and on inclined plane within the vicinity of Zvolen.

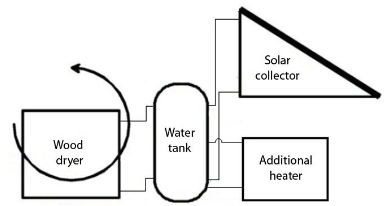

Fig. 2: Solar dryer with closes drying cycles and with binary source of energy.

Serious aspects at designing real type of a solar dryer are temperature ratios within chosen area, where should be installed this dryer. Maximal and minimal average annual (for the season) temperature in exterior within Slovakia is varying between 20-10°C, often we can meet with significant differences between daily and night temperatures.

Within temperate continental climatic zone and especially at request to meet exact data of the drying regime for sawn wood, we took a decision for a design of solar dryer with closed drying cycle process and with binary source of energy including an external solar collector, Fig. 2.

At sufficient intensity of solar radiation, solar liquid collector is engaged in operation of the dryer. At such case, heating up of drying medium will be sufficiently provided only solar energy. At insufficient intensity of solar radiation, solar collectors are exploited as additional source of heat for warming-up of water within accumulator or drying medium, eventually is turn off the collector, and as main energy source for dryer is exploited second energy source – often it is a stove fired with solid biofuels.

Determination of drying conditions and computation of heat consumption at drying of sawn wood

On the basis of experiments the technological – operating regulation was developed which determined the drying medium parameters for chosen wood species and thicknesses of sawn wood (Koberle 1982; Víglaský 1989):

- Temperature of dry thermometer t_s = 40°C
- Psychrometric difference Δt = 5 K

In the dryer with a capacity of 10 m^3, the beech and spruce sawn wood with thickness of 24 mm will be drying from the initial absolute moisture content (MC) of 80 % to final MC of 25 %. Within Tab. 1 the drying conditions for chosen beech and spruce sawn wood are shown. Drying curves according to Koberle (1982) were taken as the base for a computation of total drying time and the moisture content decrease in sawn wood within the individual drying zones (Figs. 3 and 4).

Tab. 1: Drying conditions for chosen wood species – beech and spruce sawn wood.

Wood species - sawn wood	Beech	Spruce
Dryer capacity (m^3)	10	10
Turning per year	56	106
Year capacity (m^3)	560	1060
Drying time (h)	143	74
Density of Wood ($kg \cdot m^{-3}$)	677	430

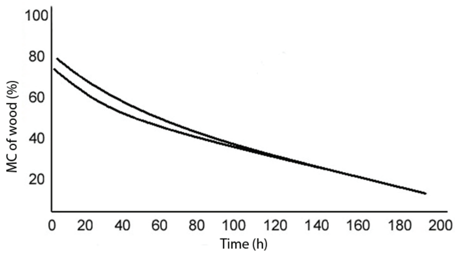

Fig. 3: The drying curve for beech un-edged sawn wood with thickness of 24 mm (Koberle 1982).

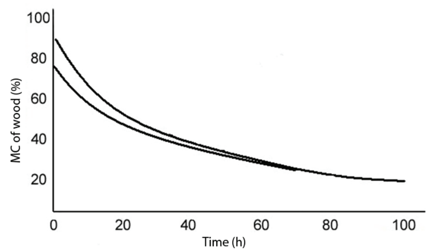

Fig. 4: The drying curve for spruce edged sawn wood with thickness of 24 mm (Koberle 1982).

At the computation of required heat for a drying process, it is needed to specify the total weight of sawn wood solids within a dryer from the Eq. (1):

$$G_S = \rho \cdot V \tag{1}$$

where: G_S - total weight of sawn wood solids within a dryer (kg),
ρ - the density of wood ($kg.m^{-3}$),
V - the dryer capacity (m^3).

Subsequently, evaporated water quantity within a dryer in the individual drying zones is derived from the Eq. (2):

$$w - G_s \cdot (u_1 - u_2) \tag{2}$$

where: w - evaporated water quantity within a dryer (kg),
u_1 - initial moisture content of wood (-),
u_2 - final moisture content of wood (-).

On the basis of above mentioned conditions, the average hour heat consumption for the individual drying zones was computed at the average specific heat consumption for evaporation of water from the sawn wood q = 3.840 $MJ.kg^{-1}$ (Víglaský 1989).

The computed values are shown with in Tabs. 2 and 3.

Tab. 2: Heat consumption according to the zones during drying of beech sawn wood (u_1 = initial moisture content of wood; u_2 = final moisture content of wood; $_\Delta u$ = difference of moisture; τ = drying time; W = evaporated water quantity; Q = heat consumption; øQ = average hourly heat consumption).

Drying zone	u_1 (%)	u_2 (%)	$_\Delta u$ (%)	τ (h)	W (kg)	Q (MJ)	øQ ($MJ.h^{-1}$)
I	80	72	8	10	541.6	2079.7	207,97
II	72	66	6	10	406.2	155.,8	155.98
III	66	61	5	10	338.5	1299.8	129.98
IV	61	56	5	10	338.5	1299.8	129.98
V	56	52	4	10	270.8	1039.9	103.99
VI	52	48	4	10	270.8	1039.9	103.99
VII	48	44	4	10	270.8	1039.9	103.99
VIII	44	41	3	10	203.1	779.9	77.99
IX	41	38	3	10	203.1	779.9	77.99
X	38	35	3	10	203.1	779.9	77.99
XI	35	32	3	10	203.1	779.9	77.99
XII	32	30	2	10	135.4	519.9	51.99
XIII	30	28	2	10	135.4	519.9	5.99
XIV	28	26	2	10	135.4	519.9	5.99
XV	26	25	1	3	67.7	260.0	86.66

Tab. 3: Heat consumption according to the zones at drying of spruce sawn wood (u_1 = initial moisture content of wood; u_2 = final moisture content of wood; $_\Delta u$ = difference of moisture; τ = drying time; W = evaporated water quantity; Q = heat consumption; øQ = average hourly heat consumption).

Drying zone	u_1 (%)	u_2 (%)	$_\Delta u$ (%)	τ (h)	W (kg)	Q (MJ)	øQ ($MJ.h^{-1}$)
I	80	68	12	10	516	1981.4	198.14
II	68	58	9	10	387	1486.1	148.61
III	58	49	9	10	387	1486.1	148.61
IV	49	42	7	10	301	1155.8	115.58
V	42	36	6	10	258	990.7	99.07
VI	36	30	6	10	258	990.7	99.07
VII	30	26	4	10	172	660.5	66.05
VIII	26	25	2	4	86	330.2	82.56

RESULTS AND DISCUSSION

The average hour heat consumption needed for drying sawn wood forms the base of solar collector's system design. The several simulations with a different number and type of solar collectors, their angle to sun and heat carrier liquid velocity were made in T*Sol Expert 4.5 simulation software. A connection with vacuum tubular collectors with a total aperture surface of around 120 m^2 with an angle of 35° to the horizontal position and orientation to the south it seems as the most effective solution (on the Fig. 5). The value of incident solar radiation energy was taken from the database T*Sol Expert 4.5. The results of the annual simulation of solar system design for sawn wood dryer are shown within Tab. 4.

Tab. 4: Results of the annual simulation of solar system at condition of sawn wood dryer.

Minimal installed collector area	m^2	111.00
Area of installed collector aperture	m^2	120.32
Energy incident on the collectors surface	$MWh.year^{-1}$	155.82
Energy acquired from collectors	$MWh.year^{-1}$	80.56
Energy from the additional heating	$MWh.year^{-1}$	340.84
Solar energy sharing on total annual consumption	%	19.10
Solar system efficiency	%	51.70

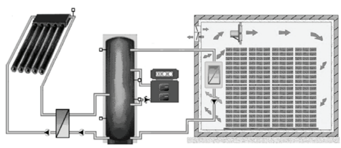

Fig. 5: Design of a solar sawn wood dryer.

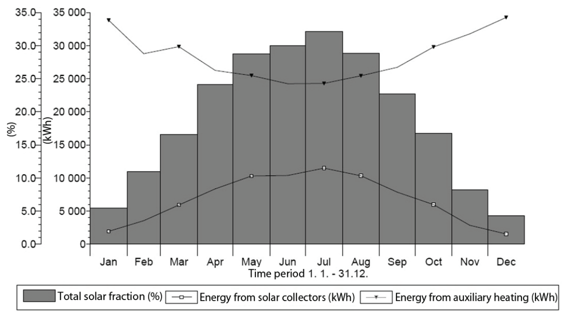

Fig. 6: Energy obtained from the solar system and energy supplied at additional heat source.

Quantity of energy which is shared on the drying process – the solar energy and energy from the additional device – and of course a percentage representation of the solar energy within the individual months is shown on Fig. 6.

At the dryer design, we considered with the additional heat device in the form of boiler for biofuel – wood chips. In the case of wood chips burning with the low heating value of 15 $MJ.kg^{-1}$, the designed solar system is suitable to save up 35 152 kg of solid biofuel annually. A dependence of saved biofuel and energy obtained from the solar collectors within the individual months is shown on the Fig. 7.

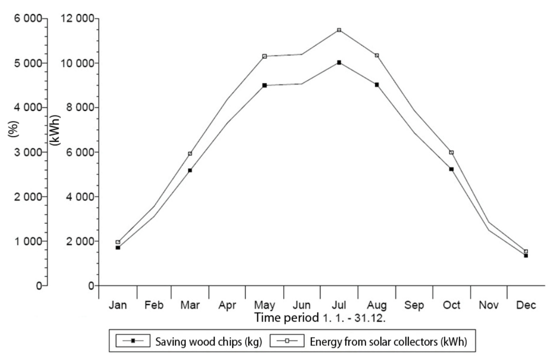

Fig. 7: Saving up of biofuel within the additional heat source.

At the simulations, the required heat of dryer was dimensioned on maximal heat consumption at the beech sawn wood drying. At the dimensioning on maximum heat consumption at the spruce sawn wood drying, the solar energy coverage was approximately the same as maximum heat consumption at the beech sawn wood drying. At the simulations, where the heat necessary of dryer was dimensioned on minimum heat consumption at beech or spruce sawn wood drying, the annually coverage of solar energy is varying between 32 and 35 % at the saving up of aperture surface size.

From the shown parameters of drying medium is obvious, that it is warm air at the low-temperature drying. Low-temperature drying, in practice called pre-drying, replaces a natural drying. In fact to a lower culmination of the final MC at the sawn wood pre-drying, the levelling can be shorter or left out (at the drying within dryer) where the energy is saved up (Klement and Detvaj 2007).

Traditionally drying has been accomplished by burning wood and fossil fuels in ovens or open air drying under screened sunlight. These methods, however, have their shortcomings. The former is expensive and damages the environment and the latter is susceptible to the variety and unpredictability of the weather. Solar wood drying is a happy medium between these two methods. A solar wood drying system does not solely depend on solar energy to function; it combines fuel burning with the energy of the sun, thus reducing fossil fuel consumption (Vijaya et al. 2012).

Other attractive features of low-temperature drying compared to natural drying, in addition to energy savings, are (Trebula and Klement 2005; Wengert 1980):

- shortening the overall drying time,
- increase quality; loss reduction on the lumber (2 to 2.5 %),
- uniform production,
- ease of drying,
- better use of dryers,
- differently species of lumber can be mixed without serious problems,
- moisture contents are more uniform than in air drying.

CONCLUSIONS

Each wood processor which works with its drying wants to achieve its required quality after drying at the lowest costs. Nowadays, we increasingly reach for renewable resources and forms of energy in each branch of industry. In the sawn wood drying area, the Sun has become known as an attractive resource of renewable carrier of energy - heat. Proposed system does not ensure a full independence of sawn wood dryers in heat provide, but it replaces some heat necessity obtained from the additional heat source.

As it is obvious from the issue of the solar preparation of warm water and heating, the solar systems can be included to the finance demanding systems from the point of capital costs. The solar sawn wood dryers commercialization can be facilitated by different government financial incentives which are determined for a solar technology support. It is necessary to awake, that in economy ideas it is not possible to quantify all advantages of the solar devices as the additional sources of heat energy – protection of environment and reduction of dependence from traditional fuels.

The results of simulations gives imagine about a device application base on solar energy exploitation within low capacity sawn wood dryers.

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Richard Bergel*, Jozef Víglaský, Marián Ježo
Technical University in Zvolen
Faculty of Environmental and Manufacturing Technology
Department of Environmental and Forest Technology
T. G. Masaryka 24
960 53 Zvolen
Phone: +421 45 520 68 78
Slovakia
Corresponding author: bergel.richard@gmail.com