GRINDED WOOD DRYING WITH COMBUSTION GASSES

Jerzy Świgoń - Jaroslav Longauer

Abstract

There were analyzed the most important problems related to right and safe operation of grinded wood drying in dryers using combustion gasses. Attention was paid to conditions of dryers selection, their technical and thermodynamic characteristic as well as methods of their control. Fire and explosion hazard was indicated. The methods of counteraction were discussed. There was revealed possible reduction of energy consumption of the process accompanied by simultaneous improvement of output.

Key words: *combustion gas dryer, recirculation, fire, explosion, energy consumption*

INTRODUCTION

The necessity of grinded wood drying, being a raw material for wood-based panels production, results from requirements of a technological process. Also more and more popular grinded wood granulation or briquetting before wood burning usually requires earlier drying of the material. Grinded wood is characterized among others by high diversification of shape and dimensions as well as by varying and very often high initial moisture content (i.e. 30-150% [1]). When drying particles for particleboards production there is required very low final moisture content (even as low as 1-2% [1]). For other purposes the final moisture content of wood may be higher, even up to 35% [3].

The above conditions result in the necessity of the proper selection of driers, which could ensure proper and safe run of a drying process with possibly low energy consumption. The paper presents the analysis of the most important problems related to grinded wood drying.

DRYERS FOR GRINDED WOOD

General characteristics

Drying loose materials, including grinded wood, is usually performed with the use of a diaphragmless dryer in which gas medium is responsible for convective heating of the material to be dried. The basic options of grinded wood drying are gas flow through immovable or mechanically mixed layer, fluidized drying or drying with pneumatic transport [4]. When high output of drying is required there are used continuous dryers usually with cocurrent flow of dried material and drying medium.

The drying medium consists of gasses being in the direct contact with the material. It carries moisture evaporated from the material. In diaphragmless dryers the drying medium is also heat carrier. It is responsible for transferring to the material heat which is required for moisture evaporation. Temperature of gasses at the inlet to a diaphragmless dryer usually is equal to ca. 400^{o}C and in some cases as high as 650^{o}C [1]. The heat required for heating up the medium comes from burning furnace oil, gas or wood wastes. When the fuel is burned at the optimal conditions temperature of combustion gas is usually equal to ca. 1200^{o}C which is too high to transfer them directly to a dryer. Therefore, hot combustion gas is first of all mixed with ambient cold air, which reduces the temperature and increases the amount of the drying medium. Instead of ambient air, hot waste gasses leaving the dryer may be used to reduce the inlet temperature, i.e. recirculation of some portion of waste gasses may be used. The main results of the recirculation are as follows [4]: reduction of heat consumption in a dryer (usually 10-20%), increase of moisture content in the drying medium (reduction of cracks, making easier to heat up particles and to get more uniform drying), reduction of oxygen content in the drying medium (reduction of oxidation of the material as well as hindering ignition of the material), making easier to control the dryer by the change of the amount of recycling combustion gas (control through moisture content of the drying medium) as well as increase of output and efficiency of the dryer (increase of the amount of moisture evaporated from the material as related to mass of burned fuel).

In respect of thermodynamics the described above and commonly applied drying processes using combustion gasses are unfavorable. It is due to the fact that the process is accompanied by high and irreversible loss of exergy (ca. 50% [2]). Therefore, it would be the most effective however, more complicated from the construction point of view, to apply combined heat and power technology.

Drying process organization

The drying time depends on the amount of moisture to be evaporated, the degree of grinding of the drying material as well as on intensity of heat and mass transfer between the drying medium and material. The drying time of individual fractions of particles introduced to the dryer differs significantly. Independently on size and the initial moisture content the final moisture content should be always the same and conforming the technological requirements.

During the proper operation of the dryer the time of the material staying in a chamber or a drum should be equal to the material drying time to the required final moisture content. Both the drying time and the time of the material staying in a dryer depend on the construction of a dryer (as designed by a designer) and on conditions of material transport in a dryer (depending on a designer and maintenance) as well as on parameters of the drying medium (depending mainly on maintenance).

Convective heat transfer has the highest contribution in heating up the material. Therefore, the construction of filling a drum or chamber has significant influence on the run of the drying process. In pneumatic and fluidized dryers the construction results from the conditions of the pneumatic transport of the dried material. In other types of dryers systems ensuring the uniform separation of the dried material are considered to be the most favorable. In order to perform the separation there are used different types of baffles rotating with a drum or stirrers and pokers used in dryers with stationary chambers. The primary task of the moving elements is to raise up the material in order to create a cascade of particles spilling across the direction of the drying medium flow. The drying process is especially intensive when the cascade is uniform in the whole section and length of the chamber. It also results in short drying times.

The transport of particles is also determined by their shift during falling down after sliding down from baffles. In the same conditions the lighter, i.e. smaller particles are moving faster. When the size of particles is the same the faster motion is related to particles of lower moisture content. Therefore, the pneumatic segregation of the falling down particles occurs in the cascade. As the result of the segregation the dryer particles are moving faster into the direction of the outlet than the particles of higher moisture content. Therefore, the time of the material staying in a dryer is diversified. However, in the well operated dryer the time is equal to the drying time of individual particles. The particles leaving the dryer, independently of their size, have the moisture content equal to the target moisture content.

The intensity of mass transfer during drying, i.e. moisture evaporation depends on intensity of heat transfer only in the first drying period, i.e. during the period of the constant drying rate. When drying rate is decreasing the intensity of mass transfer depends almost exclusively on physical and chemical properties of the material.

Deviations between the obtained final moisture content and the target moisture content are basis to make changes in the dryer operation. The most frequently applied methods of control of the dryer are as follows [4]: change of the rate of the material introduced to the dryer (in spite of the variable initial moisture content of the material the amount of the evaporated moisture should be constant), change of the drying medium temperature through the change of the amount of fuel to be burned or through the change of the amount of air cooling down combustion gasses, change of rotation rate of the moving elements of the dryer (it changes the drying time and time of the material staying in the dryer). As it was already mentioned the additional ability of the control is related to the application of the recirculation of the drying medium.

The detailed description of heat transfer and gas flow during grinded wood drying was reported in our previous work [4].

FIRE OR EXPLOSION HAZARD

Fire characteristic of drying process

Fire may occur in any system consisting simultaneously of the following three elements: combustible material, oxygen (air) and ignition source. If combustible material is present in the form of the so-called explosive mixture then explosion hazard occurs. Therefore, grinded wood drying may be related in some conditions to hazard of fire or explosion.

Wood is a combustible material and moisture included in wood makes difficult to ignition it. During the drying process moisture content is decreasing therefore, decreases wood resistance to ignition. The higher drying temperature the faster drying process is but the fire hazard increases. It may be assumed that during free water evaporation wood temperature is equal to wet-bulb temperature. Just after free water evaporation the wood temperature increases up to obtaining the dry-bulb temperature of the drying medium. Therefore, the final stage of drying is especially dangerous because of the temperature increase at low moisture content. Thermal pyrolysis of wood starts after wood drying and heating it up to the specified temperature. Then wood starts to emit among others combustible substances which may ignite in some favorable conditions. Heat of combustion produced in such conditions intensifies the pyrolysis and therefore, intensifies the combustion process. The ignition temperature of wood is equal to 270°C. However, during long lasting operation of lower temperature the ignition may even occur in temperature of ca. 150°C (in case of wood dust even at 120°C [1]).

The explosive mixture is a mixture of combustible gas or vapor of inflammable liquid or dusts of combustible materials with air, oxygen or other oxidizing gasses. At the proper concentration of components and the action of the ignition source the mixture is yielded to violent combustion connected with high increase of pressure. During the grinded wood drying the explosive gas or gas-vapor mixture might be formed when not combusted or not fully combusted gas is getting out from a combustion chamber or when the wood pyrolysis process starts. The gas and dust mixture may be formed with the participation of wood dust which is often formed during grinded wood transport. Special hazard is related to the system of dry material separation from the drying medium. The hazard is also occurring in a combustion chamber if waste wood dust is used as a fuel. The mentioned above mixtures are explosive in some range of concentrations determined as lower and upper limits of explosiveness. The hazard of explosion of the air-dust mixture is growing at the presence of little amount of combustible gasses or vapors event below the lower limit of explosiveness.

The volumetric content of oxygen in air is equal to 21%. The explosion hazard may be reduced by the reduction of the oxygen content in the environment surrounding wood due to the reduction of the ignition temperature. During the direct drying with combustion gasses the hazard of fire is lower as compared to drying in heated up air. It is due to the fact that combustion gasses contain less oxygen (usually 13-15% [1]). However, the limit of the oxygen content, which preserves against the explosion, should be equal to 10-11%. In the case of fire preservation the oxygen content should be even lower [6]. The oxygen content is also reduced by moisture evaporated from wood and taken by the drying medium. It also reduces probability of fire occurrence. During drying both in air and combustion gasses, the oxygen content in the drying medium will be always higher than the safe limit of fire and explosion.

Energy carrier which is able to supply the system with the ignition temperature is called the ignition source. The main source of that is heat. It may come from an outer source (i.e. being outside a dryer) or inner source (e.g. from exothermic reaction). When an inner source is used it is called self-ignition. In diaphragmless combustion dryers the cause of fire may be uncontrolled propagation of open fire form a combustion chamber of a dryer. Fire may be also caused by mechanical or electrical sparks. Mechanical sparks are incandescent particles of metal or other materials characterized by small mass and high mobility. In drying process sources of such sparks may be repair works (welding, grinding), improper run of combustion process in a furnace of a dryer or technical defects of movable elements. Electrical sparks have other immaterial character which are created for instance during coupling electric circuits, as a result of electric motors sparking or due to equalization of electric charges. Dry particles of wood are dielectrics. Therefore, conditions favoring high electrization are related to movement of the particles. Particular type of electrical sparks are ones caused by atmospheric discharges.

Depending on the configuration of the above characterized elements the following hazards may occur: uncontrolled thermal decomposition of the dried material, fire of a dryer and combustion of the dried material, snorking out (insignificant increase of pressure without combustion reaction) which may cause blast and pulling-off subsided material and leading to creation of dust mixture, gas or dust explosion which may lead to damages of installations and buildings.

The drying medium flow occurring in a dryer facilities heat and mass transfer but it also favors fire propagation. When the mixture of combustion gasses and air is the drying medium then the fire hazard is decreasing because of the limited content of oxygen in the medium. However, additional hazard appears related to possible flow combustion gasses and sparks as a result of anomalous combustion. So that high temperature drying of wood in combustion gasses may cause high risk of fire and explosion.

Counteraction of fire and explosion

Fires and explosions cause high material losses and create menace of humans health and life. Therefore, it is necessary to counteraction it. Frequently applied in grinded wood drying partial recirculation of the drying medium increase moisture content of the medium and limits oxygen content at the inlet to the dryer. It is a step towards creation incombustible atmosphere inside a dryer through the decrease of oxygen concentration below the value indispensable for explosion occurrence or sustaining combustion reaction. Other method of fire and explosion counteraction during grinded wood drying are presented in the literature, e.g. [5], [7].

EFFECTIVENESS OF DRYING PROCESS

Effectiveness is a result of operations which is described by a relation of obtained effects and sustained inputs. It is assumed that drying process is more effective as less energy is used for drying possibly the highest amount of material. Therefore, an energetic efficient dryer is the one that works high output at low energy consumption. In last decades there was significant progress in the area of identifying and decreasing energy consumption of timber drying. Whereas, much less works were done on energy consumption of grinded wood. According to the data from 2001 wood-based panels production in Poland was 13% higher as compared to sawn timber. However, energy consumption in wood-based panels industry is four times higher as compared to sawn timber industry [8]. The main cause of the high energy consumption in wood-based panels industry is heat demand in the process of particles drying. Therefore, it is justified to find possible methods of reduction of energy consumption during grinded wood drying. The performed analyses [8] show that actions on reduction of energy consumption of dryers simultaneously lead to improvement of dryers output (Fig.1).

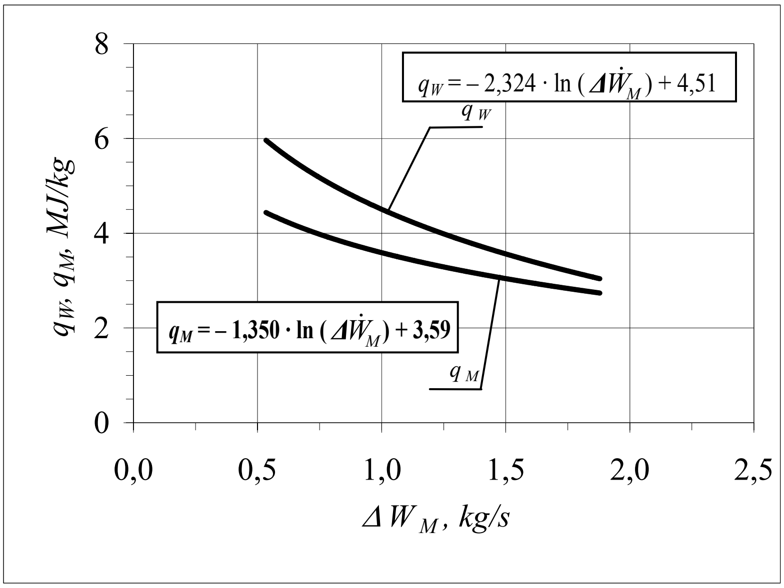

Fig. 1 Dependency between energy consumption of drum dryer and their output $\Delta \dot{W}_M$ [8]

CONCLUSIONS

1. For the sake of specific character of grinded wood the material is usually dried with the use of diaphragmless dryers using hot combustion gasses as the drying medium. As a rule the dryers are cocurrent with partial recirculation of the drying medium. During the rational operation of such dryers the time of the material staying in a dryer should be equal to the drying time. The fulfilling of the relation depends among others on conditions of heat and mass transfer in a dryer and conditions of the material transport in a dryer.

2. In some conditions grinded wood drying may be related to the hazard of fire and explosion. Drying in combustion gasses and their partial recirculation reduces the degree of the hazard.

3. In respect of thermodynamics drying in combustion gasses is unfavorable because it causes high and irreversible loss of exergy. It is also characterized by high energy consumption. Therefore, it is justified to find possible ways for decreasing energy consumption of grinded wood, which simultaneously leads to increase of the process output.

REFERENCES

1. Drouet T.: Technologia płyt wiórowych. Wydawnictwo SGGW, Warszawa 1992.
2. Guzenda R., Polcyn F.: Wpływ recyrkulacji spalin na bilans energii i bilans egzergii suszarek SBW-3 do wiórów drzewnych. Zeszyty Naukowe Politechniki Łódzkiej (356), Inżynieria Chemiczna nr 14, Łódź, 1987, s. 184-191.
3. Klement I., Osvald A.: Sušenie dreva z hl'adiska požiarnej ochrany. Technicka univerzita, Zvolen, 1997.
4. Longauer J., Świgoń J.: Aerodynamika hydrotermickych zariadeni drevopriemyslu. Vedecké študie, TU Zvolen, nr 11 (1996/A).
5. Markowski A. S.: Niebezpieczeństwo wybuchu i pożaru w instalacjach suszarniczych. W: „Nowoczesne techniki suszarnicze, materiały I kursu”. Instytut Inżynierii Chemicznej Politechniki Łódzkiej, Łódź 1987, s. 302-326.
6. Marutzky R.: Zum Sauerstoffgehalt von Trocknungsgasen in Spänetrocknern. Holz-Zentralblatt 49/1978, s. 751.
7. Świgoń J.: Zagrożenia pożarem lub wybuchem przy suszeniu rozdrobnionego drewna. W: „Zagadnienia współczesnej ergonomii w sektorach leśnym, drzewnym i rolnym. Monografia.” PTErg. Oddz. Pozn. i Katedra Użytkowania Lasu AR Poznań, 2005, s. 105-112.
8. Świgoń J.: Efektywność procesu suszenia wiórów drzewnych w zakładach płyt wiórowych. Roczniki Akademii Rolniczej w Poznaniu, Rozprawy Naukowe, z. 346, Poznań 2004.

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