Popular Article _____Chapter- 10

DIELECTRIC HEATING: AN ECO-FRIENDLY ALTERNATIVE FOR DRYING OF WOOD

Rohit Sharma, Rakesh Kumar and Souvik Ray*

Abstract

Wood is a biological material, consisting of cellulose, hemicellulose, lignin and extractives. Freshly sawn wood needs to be dried properly before any further utilization. Dielectric material is very good insulator which gets heated up under high frequency and this technique is being used in several sectors such as food, textile and medicine. Though dielectric heating is known as useful technique,it is stillnot properly utilized in wood sector. Heat is required in most processes in wood industry starting from wood drying to the manufacturing of engineered wood. Traditional method of wood dryinginvolvescoal driven energy which is detrimental. Dielectric heating uses less electricity as compared to conventional method of heating in wood sector and is green and ecofriendly technology. Moreover, the burning of wood-based waste generates harmful gases for environment; dielectric heating reduces such factors. Along with wood drying, dielectric heating can be used in other wood processing fields like engineered wood and phyto-sanitation. Thus, dielectric heating system may provide a better eco-friendly alternative in wood sector to fulfil the energy requirements.

Key words: Dielectric heating, Wood drying,Conventional kiln, Engineered wood,Eco friendly.

Wood Processing Division, Institute of Wood Science and Technology, 18th Cross Malleswaram, Bangalore – 560003, India
E-mail: rohitsharma.fri@gmail.com

Introduction

Dielectric materials are very good insulators or we can say they are a poor conductor of electric current.The dielectric material is such material which get polarized by applying electric field. When this happens at start there is no flow of current through them unlike metals where free electron or loosely bound electron drift through the material (Jones, 1986). Instead, dielectric polarization occurs as electric charges shift from their average equilibrium positions. The polar molecules contain dipole moment, when these molecules are exposed to the electric field they tend to align in the direction of field.

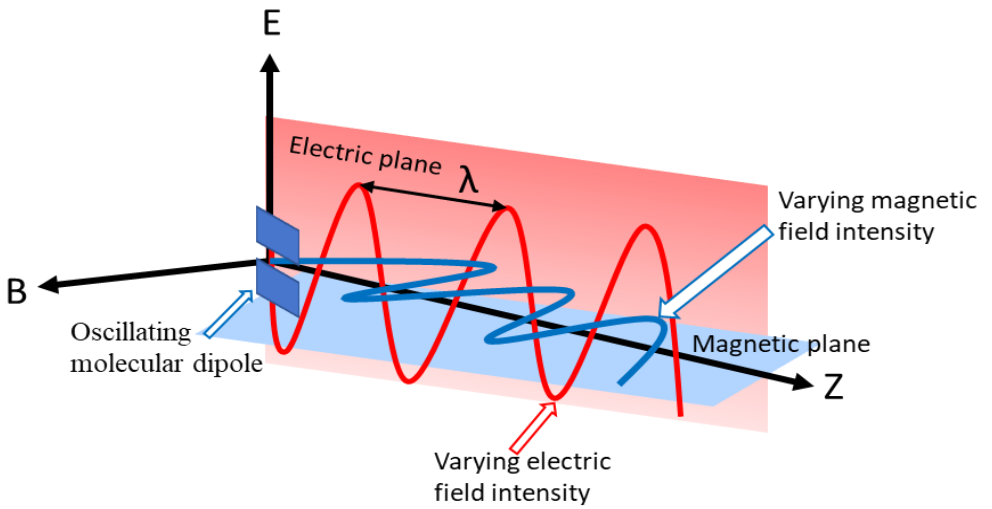

Fig. 1: Propagation of Electromagnetic Waves

When the applied electric field oscillates, these molecules start to move and rotate in order to keep them aligned with the field. With the change in field direction the molecules also change its direction in reverse and this phenomenon is called "Dielectric Rotation"(Mijovidand Wijaya, 1990; Grant and Halstead, 1998).

The temperature of the molecule depends on the kinetic energy of the molecules. When dielectric rotation takes place, it increases the kinetic energy of the molecules which ultimately results in increased temperature of the molecules. When these molecules come in contact with each other and collide,it resultsin the transfer of the energy to other part of the material thus heating up the material. And thus, heating by dielectric rotation in material is often known as dielectric heating. The heating in this case is done by using the electric fields of high frequencies or the electromagnetic fields. The functioning of the dielectric heating system depends upon the frequency and the wavelength of the applied field (El Khaled et al., 2018).

Microwaves and Radio frequency electromagnetic radiation are the most commonly used high frequency waves to heat up the dielectric material.Radio frequency (Rf) and microwaves radiation frequency ranges from 3kHz (Kilohertz) – 300MHz (Megahertz), and 300MHz – 300 GHz (gigahertz), respectively. Wavelength for Rf and MW

(Microwave) ranges from 1m – 100km, and 1mm – 1m, respectively as shown in Fig2 (Ramaswamy and Tang, 2008).

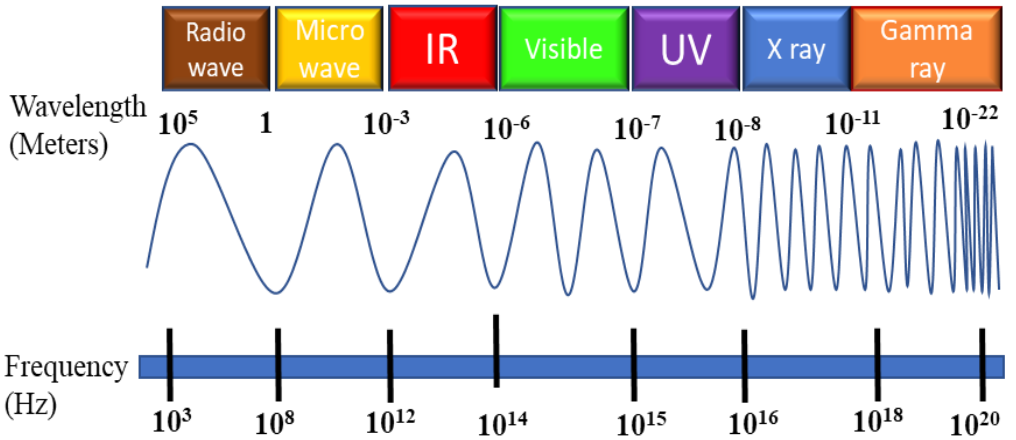

Fig. 2: Electromagnetic spectrum

Microwaves and Rf have a wide range of application in our day-to-day life. Microwave oven is the most common appliance in today's kitchen. Microwave radio spectrum used for the analysis of the material, guide aircraft to land safely. In food industry microwave is used for heating, baking, cooking, and wastewater management. Radio frequencies are generally used in communication devices such as transmitters, receivers, mobile phones, television. It can radiate into space as electromagnetic waves as this is the basis of radio communication technology. It is being used in wireless communication such as cellphones. It has several applications in the field of medical science. Ability of these electromagnetic waves to heat up the dielectric material haswidened the scope for their applications. They can be potentially utilized in the field of wood science because of their ability to provide heating.

Potential Utilization of Dielectric Heating in Wood Sector

Wood is an organic material, consisting mainly cellulose, hemicellulose, lignin and extractives. Living tree imparts resistance against wood decay agencies like fungi and insect due to presence of secondary metabolites like phenolic compounds in hardwoods and terpenes in softwoods. Once the tree is felled it starts losing its resistance against foreign invaders.Freshly cut wood has a moisture content of 150%-200% which has to be reduced to 8-12% before putting the wood under any use.

Water in wood exists in two forms i.e., free water and bound water. Free water is the water available in cell cavities or lumens and not chemically bonded with wood. It is easy to remove and does not have any effect on the wood properties. Bond water is chemically bonded with wood and is present in the cell walls. The bond water removal from wood invites a lot of changes in wood properties. As the water continues to decrease from wood,there is a point when the cell lumens are completely empty while the cell walls are fully saturated with bond water. This point is called FSP (fiber saturation point) (Gezici-

Koç et al., 2017). When wood starts drying below FSP or when the bond water starts to get removed from wood, the cell wall starts to shrink. Moreover, when the dry wood absorb water in cell wall it tends to swell. This shrinkage/swelling of wood causes problems in the end product when it comes in contact with moisture (Mantanis et al., 1994).

The shrinkage/swelling is different in different woods and even in different direction of the same wood because of the anisotropic nature of the wood. Different woods have a complex anatomy hence require attention before any treatment. Some species of wood which are easy to treat with chemical preservativeare called non-refractory woods.Thespecies which are difficult to treat or hard to dry are known as refractory wood. Permeability ofa wood is ease of flow of fluids; hence wood with low permeability is difficult to treat with chemicals. These chemicals are used for the enhancing the life span of wood and are called wood preservatives.

The wood sector requires different techniques of heating. In case of solid wood,energy is required for seasoning purpose while in case of the engineered wood the energy is required for drying as well as the curing of adhesives.

Drying of wood using dielectric heating is not quite common, but can be a good substitute to the conventional drying because of its possibilities of drying faster than the conventional dryers with preserved quality. This technique can be very beneficial in case of higher moisture content gradient (Hansson, 2007).High frequency drying of wood is cost effectivesince it saves plenty of time and involves fewer human resources. The quality of the product is also better than that of wood dried using ordinary kiln (Vermaas, 1973). Generally, the Microwave and Radio frequency electromagnetic waves are used for the heating purpose and their utilizations are restricted in wood sector because of lack of awareness. Dielectric heating systemhas certain benefits over the normal heating methods and can be useful for wood sector in many ways.Dielectric heating pretreatments are useful to increase the performance of refractory wood species and difficult to treat wood species can be utilized easily at industrial level. The treatment will improve the treatability class of timber by improvement in retention and penetration properties of wood (Samani et al., 2019).All these processes demand high energy consumption. Dielectric energy has the potential to replace the traditional method of energy generation in an efficient manner. Although air drying and solar kilns are the environment friendly options for wood drying, but they are very time consuming hence we cannot use them as the industrial production is time bound. In this scenario the alternative which is eco-friendly and also time efficient is required; hence dielectric heating fills the void perfectly.

Use of Microwave in Wood Sector

As we already know the microwave frequency ranges from 300MHz to 300 GHz and wavelength from 1mm to 1m (El Khaled et al., 2018).Microwaves are produced by magnetron for industrial as well as for domestic purpose. Microwaves heat the material by dipole rotation mechanism. Microwave heating system have numerous advantages over normal conventional drying method. In conventional kiln drying methods the time is the biggest concern. In air drying and Solar kiln drying the time for drying of wood can be several months at fastest. While other steam heated or electric kiln can take two – three weeks for some woods which are hard to dry due to their complex anatomy. Conventional

kiln running on wood waste as a heat source releases too many gases due to burning of the waste contributing to environmental related issues.

Dielectric heating using microwave is comparatively an eco-friendly approach of wood drying. The wood dried by conventional method tends to develop numerous defects and these defects reduce the value of the product.Defects can be reduced by taking more care during drying which will increase the time of drying and also makes it alabor-intensive. Drying in the conventional method is done by conductive heating method. In this, the moisture starts to disappear from surface of wood and gradually from the subsequent surfaces. Moisture movement in this case is because of the moisture gradient (Resnik et al., 1997). Sometimes due to rapid drying the moisture gradient becomes more in the subsequent surfaces of wood, which results in the development of drying defects like, cracking, warping, checks, splits etc.

In microwave drying system, the drying is done by the convective heating method. The drying starts from the core of wood and gradually moves to the surface. In this, the heating takes place at points where the water molecules are available in abundance. Moisture gradient does not play any role in this system of drying hence chances of developing of seasoning defect reduces. It is an ecofriendly method of drying of wood, as it needs less electricity than we need in conventional electric heating kiln.The wood species which are hard to dry are also hard to treat when it comes to preservative treatment. Low permeability can be caused by anatomy of wood or may be because of natural barrier. Microwave radiation when penetrate the wood at high intensity they sometimes damage the wood structures and break these natural barriers. This action of MW results in the increased permeability of wood. Hence, the penetration and retention of wood preservative is improved with the help of microwave pretreatment.

Globalization of any sector is an important aspect. In wood sector, proper precaution is required while importing and exporting goods on international level. Wood can be a carrier to fungus, insect and other organism. Therefore, the process of Phyto-sanitation before export or import of product is important. Wood based packaging material is being used to pack other material so this packaging material also needs to be properly sanitized. Currently fumigation using Methyl Bromide is being used for the Phyto sanitation of wood as per ISPM no. 15 standards. MeBr (Methyl Bromide) is very hazardous and non-ecofriendly so it becomes necessary to look for better alternatives and microwave heating is one of them. Use of microwave for Phyto sanitation has been described in ISPM no. 15 also. Although, conventional heating can also be used for the purpose of Phyto-sanitation but again it is very time consuming and more exposure under heat may degrade the properties of wood. In case of di-electric heating, we will need to decide the parameters for the treatment of a particular wood. It is a great alternative and has the potential to replace the MeBr on global level for Phyto sanitation.

Use of Radio Frequency waves in Wood Sector

Radio frequency waves have a frequency range of 3KHz – 300MHz and wavelength from 1m – 100km (Ramaswamy and Tang, 2008).Heating mechanism of this radiation is also on the basis of dipole rotation movement. It is more or less similar to Microwave heating system, although there is a small difference between the two. RF can penetrate easily to deeper length while microwave takes more time for the same amount of length.

Easy penetration to the core of the wood in small time leads to uneven drying of wood hence, this method is less preferred for wood drying. Despite this limitation some of the wood species which are easy to dry and do not develop any drying defects can be dried using this technique.

This technique holds a great role in the field of engineered wood industry. In wood composite we use different hot setting adhesive which need particular temperature for curing. This can be achieved during pressing in hot press. In hot press there are two plates, they heat up to required temperature and composites are pressed in between these plates. Dielectric heating is suitable method if we have to monitor the curing of PF adhesives. Thickness of board influence the curing rate of adhesives. As the thickness of board increases the cure rate decrease and it is highest for thinnest board (Karič et al., 2007).Heating using RF this problem can be eliminated as RF heating is based on convective type of heating. In RF heating system the heating is even throughout the composite and proper curing is done. In case of the thick composite the heat does not travel properly to the core of the composite and curing of adhesive becomes difficult in conductive heating. To achieve the required temperature, we have to wait for longer time which is not desirable as it can affect the other properties of composite. RF heating technique is quite helpful in this scenario, as RF heats the material by convective method hence, the thickness of the material plays no role in this case.The dielectric of high frequency heating is a great alternative to the conventional heating method as it reduces the press cycle, platen temperature and post curing time, and constancy of resin formation. RF heating as an alternative energy source offer various advantages over thermal cure. These includes, faster cure time, higher efficiency and production rate, and uniform heating.RF also plays an important role in Phyto sanitation. Comparative study on the performance of Microwave and Radio frequency waves for Phyto sanitation has been done and result shows that both the techniques can be used for the purpose (Dubey et al., 2016). RF heating has been given the better uniform heating than MW under given condition. This can be the preferred alternative to methyl bromide (or conventional heating).Because of increasing environmental concerns, the dielectric heating approach is of value to the wood treating industries (Smith et al., 1996).The dielectric heating technology brings new inputs in field of product development in traditional industry and also provides with energy and material savings significantly (Torgovnikov and Viden, 2010).

Future and Scope of Dielectric Heating in Wood Sector

The field of dielectric heating in wood sector is yet to be properly explored in country. The technique provides huge advantages over the normal conventional drying with some additional perks in property improvement. The wood generally used by the industries are plantation grow which needs to be treated. Being fast grown plantation, the chances of the growth stress development are also high which affect the processing of the timber. Eucalyptus like timbers with high growth stresses required more care. Dielectric field open the new ways of timber treatment and modification. Dielectric treatment of wood enhances the property for preservation and retention but also shows some negative effect on the strength properties of the wood. Optimizing the parameters for dielectric treatment of particular species become very necessary as one cannot compromise with the

strength loss of timber. Use of dielectric heating other than seasoning and preservation of timber can be explored. Dielectric heating can be used for the curing of hot setting adhesives like PF, although the application is already in progress in plywood sector the further extension can be done in the making of the CLT (Cross laminated timber) and GLT (Gluelaminated timber). In case of timber laminates, the use of hot setting adhesive is restricted because, the curing in the core of laminate is not easy as the heat transfer start from surface to the core in normal hot press machines. Dielectric heating can be applicable in such case and can give good result as in case of dielectric heating the heating does not start from the surface. Instead, the presence of polar molecules will heat up the core and surface uniformly and can be used for the same purpose. Wide utilization and anisotropic nature of wood increases the research scope of dielectric treatment in the country.

Conclusion

Moist wood is attacked by the microorganism, and drying reduces the chances of degradation of wood. The drying of wood by conventional methods takes long time duration and high energy. Dielectric heating process is energy efficient technique of wood drying with minimized defects, improved properties, economical and ecofriendly. Apart from drying it may be an ecofriendly alternative for Phyto sanitation of wood as it can replace the Methyl Bromide treatment which is very hazardous to mammals and environment. Dielectric heating is an environment friendly approach for wood industry as it reduces the processing time and use of energy becomes minimal thereby reducing the processing cost.

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