From Oscillation to Heat

Many of the steps in the field of drying and bonding of wood as well as drying of varnish are pure heating processes. In conventional processes, such as in case of a heated veneer press, the principles of heat transition and heat conduction are valid. The material is heated up from the outside to the inside. There is a great disadvantage, because more or less volumes of wood must also be heated up before the required amount of heat may be transferred to a bonding juncture. The opposite is true with the application of high frequency (HF). This technology has been used for decades, resulting in a considerable reduction of the processing times in various fields of production.
Due to the poor heat conduction of the wood, the heating processes require a lot of time. With an increasing thickness of the wood, the time required for the transfer of heat to the target position (such as the bonding juncture) will also increase, resulting in long processing time. Complete heating-up of the carrier material will also take place, which may be undesirable for reasons of fast subsequent treatment.
The initial position is quite different with the application of high frequency (HF). The high frequency energy is transferred to heat directly within the wood, so we can say that the wood is heated from the inside to the surface.

The Principles of High Frequency Technology

By using high frequency technology, for instance for bonding purposes, the wood or the carrier material and the bonding agent are exposed to a capacitive or dielectric heating process in an alternating voltage high frequency field.
In simple terms: the smallest components of water present in the wood, the molecules, behave similar to small magnets in a magnetic field. The molecules are subjected to high frequency oscillations, resulting in the generation of heat due to friction caused by mutual obstruction.
The figure shows disoriented water molecules in wood. Due to the influence of the electrical field, the molecules are oriented perpendicular to the electrodes. With each change of polarity of the alternating voltage applied, they perform a change of direction by 180º, thereby resulting in the desired generation of heat. The repetition rate of this procedure is determined by the frequency, which is located in the MHz range. This means, that the molecules change their direction and move several million times (!) per second. The bonding juncture is heated up directly with higher intensity and faster than the surrounding wood when the high frequency alternating voltage is applied, because it represents considerably higher dielectric losses. This phenomenon is also called "selective heating".
Water molecules, the so-called dipoles, are increasingly deflected from their at-rest position with closer proximity of the voltage to the electrodes. It is easily understandable, that a greater amount of friction work is performed with an increase of the distance - whereby the generation of heat will increase by a square-law function with the voltage applied. That is, if the voltage applied is doubled, the generation of heat will be four times as high.

The Physical Context

It is not without consequence, whether a specific voltage is applied to a capacitor with plates separated by 3 cm or by 10 cm. For this reason, the voltage U (V) must always be referenced to the distance d (cm) in order to clearly define each case. This is performed in a homogenous field by dividing the voltage U applied to the electrode by the distance d between the electrodes. The resulting voltage per cm (V/cm) thus obtained is the field strength E.
The field strength, however, may not be increased at will, because otherwise flashovers or burning of wood might take place.
Some further important Factors for determining how fast and well the wood may be heated are the so-called material-dependent dielectric constant epsilon and the loss factor tangent delta.
The dielectric constant epsilon tells how many times the capacity of a capacitor with a dielectric is larger

Electrolux Macedonia
Bitola/Europe
+389(0)47 203 330
www.electrolux.mk www.elektroluks.mk www.elektroluks.eu
electrolux@t-home.mk elektroluks@t-home.mk

than an air capacitor with the same dimensions. The loss factor may be compared with the power factor cosine phi in heavy current technology. It indicates the percentage of the power converted into heat, and therefore serves as an indication of the actual "heat yield" from the electrical energy applied.

Properties of the Material

Wood is a very heterogeneous material. The electrical properties do not only depend on its characteristics, but also on the grain direction, temperature, humidity, and on the frequency applied. With degrees of humidity as generally permitted for finished products of the wood industry (furniture, design elements), i.e. with a water content of about 8 - 12%, wood may still be regarded as a "dielectric". The formulas valid for high frequency heating of isolating material may thus also be applied for wood.
It may generally be assumed that the dielectric constant epsilon at a specific frequency will increase slightly with an increasing degree of humidity, while the loss factor tangent delta will remain approximately proportional to the content of water.
Special advantage is taken of the fact during bonding with high frequency, that bonding agents feature loss factors up to 40 times higher than wood. The bonding junction may thus be heated up with a minimum of energy. Bonding times of several hours (in case of cold bonding) may thus be reduced to several minutes only.

Glues and Adhesives for High Frequency Applications

Polycondensation glues and polyvinyl acetate glues are especially suited for high frequency bonding. If only resistance against cold water is demanded from the bonding procedure, then artificial resins based on urea or melamine are to be preferred, which start bonding at 70 - 90ºC. If the bonding junction should also resist boiling water, however, then phenol or resorcin resins are called for, which however require a higher bonding temperature.
These glues are commercially available in powder form and may be mixed with water to a paste ready to be applied. They may also alternatively be purchased in liquid form with a specific resin concentration. Various artificial resins must however be mixed with a curing agent before processing, in order that the required chemical reaction for the bonding process may be started. This curing agent is a chemical substance, partly in liquid or crystalline form, causing the bonding or polymerization of the artificial resin. Such a polymerization is an irreversible chemical process, so that the resin may not be loosened or softened any more after the conversion. Materials behaving like this are in general also called duroplastics. Due to the fact that the artificial resin will get very hard, it will also represent a heavy load for the tools (planers, milling cutters, grinding belts etc.).
These problems are avoided with the use of glues on the base of polyvinyl acetate (PVA). Other than with the use of the above-mentioned duroplastics, this is thermoplastic glue, i.e. the resin is not subjected to a chemical conversion during the heating process, only the excessive water content is ejected. The glue will therefore not get as hard as in case of the duopolistic, and it may also be plasticized again after cooling down by means of subsequent heating. The plasticizing point is at around 40 - 70ºC. This is also the reason, why thermoplastic glues reach their final hardness only after the adhesive junction has cooled down. The strength is sufficient; however, that the work piece may be unclamped in warm condition after the water has evaporated. PVA glues are preferred where no extraordinary requirements with respect to strength of the junction are specified, and where protection of the tools is important.
Glues on the base of polyurethane (PU glues) also appear on the market lately. With this kind of glues, curing takes place by polymerization. A choice whether thermoplastic or curable synthetic resins should be used, depends only on the intended use of the product.

Advantages at a Glance

The most important advantages of high frequency heating are summarized as follows:

- Increased speed of production: The heat is not supplied from the outside, but is generated in the adhesive junction or in the wood without any heat conduction loss.
- Accuracy of dosing: The heat supplied may be controlled by means of microprocessors, independent of any fluctuations of the power supply or varying material characteristics. The heat may be regulated within predefined limits.
- Uniform quality: Due to the fact that the high frequency heat results in a local limitation of the heat, exact dosing, high processing speed and the lack of deformation will result, so that the products will be well-balanced and of superior quality.

Areas of Application for High Frequency Procedures

The high frequency process is not a new technology. It has already been used in woodwork and wood processing for several decades. Above all only drying and bonding of wood have been of importance up to a while ago. But some other areas as well, such as the drying of water lacquers, seem to be strictly predestined for the application of high frequency. It may be expected, that this technology will become increasingly important in respect to the rationalization and reduction of manufacturing processes.
High frequency technology is preferably used in the area of wood drying, if the goods to be dried are components which are thick, preformed and do not comprise excessive humidity. Opposed to the convection drying process, drying is here performed from the inside to the outside. Excessive drying speed might therefore result in an explosion.
High frequency is also used for the bonding of wood, either as a continuous or as a stationary procedure. Broadside, longitudinal and surface area bonding (as with the manufacturing of parquetry, solid wood panels or glue bonding) may also be mentioned in this context. High frequency treatment has not been very important in the lamination of window frames, but there may be potential applications ahead in this area.
An abbreviated processing time may be achieved with high frequency heating in the production of particle and MDF boards.
A field of application which is still very young, but which seems to have a promising future, is the drying of water lacquers. A Hessian manufacturer of stairs has commissioned such a plant only last year, which is the first one worldwide. The drying and processing times could be reduced extremely, and the required manufacturing area was reduced to a minimum.

Environmental Aspects

Special frequency bands are assigned by law for the industrial application of high frequency in order to avoid functional disturbances (according to European Standard EN 55011): 13.56, 27.12, 40.68, 2450, 5800 and 24125 MHz, each with a small tolerance range. These frequencies are available for industrial,

commercial and medical applications within Europe.
The frequency of 13.56 MHz is most often used for the bonding of wood, because it heats up the wood thoroughly and provides an equal voltage distribution within the pressed goods. The high frequency stability is of paramount importance here. This stability may not be attained without special measures. A further aspect is the influence on humans and other living creatures. High frequency radiation is absorbed by the tissue of the body, resulting in an increase of the tissue temperature. This effect may be especially pronounced in case of microwaves (e.g. 2450 MHz). Such equipment must be totally shielded for this purpose, whereby a microwave oven also belongs to this category.
All components must be carefully shielded even at lower frequencies (e.g. 13.56 MHz), so that the operating personnel will be absolutely protected while performing their duties.
With these prerequisites fulfilled, high frequency is a form of energy which is very beneficial to the environment, because no other pollutants or substances harmful to the environment may appear.

Products

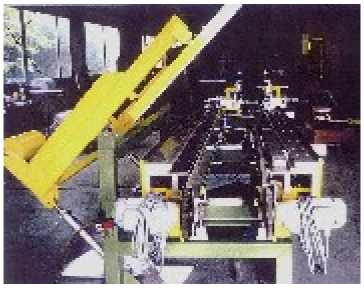
Name	Frequency	RF output power	Technology
DG 100	13.56 MHz	100 kW	electronic tube
DG 150	13.56 MHz	150 kW	electronic tube
DG 200	13.56 MHz	200 kW	electronic tube
DGT 5	13.56 MHz	5 kW	solide state
4000 T	27.12 MHz	1 kW	electronic tube

Higher power and other frequencies on request.

DG generator 230kW

DG generator 150kW

Heating-press for door handles



Heating press for window frame-gluing

Applications

Wood

	Advantages
Drying	3 times shorter process time than with hot air no overheating (the heating energy is negligible when water is out)
Gluing	100 to 20 times shorter process time no overheating selective heating
Restoration	elimination of parasites without chemicals no toxic process

Polymers

	Advantages
Welding	
Thermoforming	Shorter process time

Curing	

Food

	Advantages
Defrosting	shorter process time (factor 50) lower bacterial contamination possible with packed food
Backing and post backing	shorter process time separate control of surface and core heating rates
Pasteurization	shorter process time possible with already packed food

Various

	Advantages
Textile dryers	moisture removal in roving and bale form no overheating
Fiberglass drying	moisture removal in roving and bale form no overheating
Elimination of parasites in corn	no toxic process
Paper drying	No overheating
Book drying	No overheating
Tobacco drying	No overheating
Paint drying	Short process time No overheating