Determination of some influencing parameters in the rotational wood dowel friction welding process for the production of hand-crafted solid wood furniture using manually operated cordless screwdrivers

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Abstract
Wood welding is probably the most innovative system to obtain wood-to-wood joints of the last decades. Rotational welding basically consists on induced heat produced by friction of high-speed rotation dowel in a drilled hole with smaller diameter. Otographic, and polymeric materials begin to melt when temperature increases over 180 °C. Solidification of the melted wood after cooling and pressure leads to densification of the bonded interface [1, 2]. Nonetheless this technique is not reported used industrially because the industrial machineries and processes are not yet considered suitable for the rotational dowel welding characteristics. This poster shows advantages in the joint when welding is produced by manually operated cordless screwdriver instead of the classic static drill. The most important factors for quality of the joint are mentioned and analysed.

Problem analysis
133 million tons of artificial adhesives are spent by the wooden industry every year. Some of them are acute toxic and sensitising. So there would be a huge market share for any substitute. Metal and plastic mechanical joint is not the most suitable solution because they have to be separated at the end of the life of the furniture. Several previous studies have already been led in rotational wood welding process, but they always were separating pillar drills or automatic welding machines. Consequently there was a lack of knowledge for the manually operated cordless screwdriver in this technology.

Determination of some influencing parameters in the rotational manually operated cordless screwdriver in this technology.

The four steps in the process
Stage 1: Rotational speed friction. The temperature rises contact of the participating areas.
Stage 2: Melt temperature. Wood components melt and drain in between the two pieces.
Stage 3: Static friction process. Rotation stops and activation is top
Stage 4: Cooling down. The joint is obtained.

Involved substances...
Lignin: Branched polymers with less regular structures, repeating units are p-coumaryl alcohol, coniferyl alcohol and sinapyl alcohol.
Hemicellulose: Various sugar units, short and branching molecular chains, Pentoses, Hexoses, Hexitol, Hexuronic acids, Deoxy-hexoses.

Comparison of all (average)
- standard
- furfuryl alcohol
- turned down dowel 100/87
- oven-dry dowel
- spruce perpendicular
- spruce parallel
- C₅H₉O₂

Furfuryl alcohol
The dowels were deeped into a furfuryl alcohol bath 30 minutes of vacuum have been applied to empty the surface wood cells from air. Impregnation has been attained releasing the pressure up 1 psa.

Furan strength at N/mm²:
- 2 furfuryl alcohol
- 3 oven-dry dowel
- 4 turned down dowel 100/87
- 5 psa (reference)

Overview tensile strength of serial 1 to 7

Welded surface in the glue-line
During the rotational wood friction welding process the dowel is reduced to the substrate hole diameter. For the calculation of the tensile strength this diameter is in use:

A = 2 * rₐ * π * hₐ

Recommendations
For an easy handling rotational wood dowel friction welding process and high values of the wooden joints use a powerful manually operated cordless screwdriver with high turning moment and several gears. The drill chuck should have a capacity of more than 10mm. Lithium-based rechargeable batteries provide high energy density and prolong life service and are therefore adequate for this process.

Future Developments
The adaptation of the cordless screwdrivers to the characteristics of the rotational dowel welding process and the development of additional devices for the manually operated cordless screwdriver could help to improve the process reliability of the rotational wood dowel friction welding. For example a collet chuck would reduce the forces of torsion to the dowel and an angle fence would speedup the process in general. A digital display which shows the rotations per minute and the welding time would make the application much more easier. A manually operated cordless screwdriver with several gears could be adapted to almost any welding depth.

Literature Cited

Targets
The main goal of this study was the determination and optimization of basic parameters. Influence of the welded wood specie, direction of the grain as well as the relation of the dowel/substrate hole diameter have been analysed. Mechanical behaviour of different kind of assembly (“through” and “stop”) have been compared. Furfuryl alcohol impregnated dowels have also been drilled to determine the effect of the chemical bond line. A complete overview of the results achieved with a manually operated cordless screwdriver is reported here.

Material and methods
The material for the samples is fagus sylvatica and picea abies. The dowels were welded parallel and perpendicular to the grain into a depth of 2 x 20 mm. The size of the samples was 50 x 50 x 20 mm. Standardized fluted dowels of a diameter of 10 mm were in use.

Cordless screwdriver and process
The two parts of the sample have been drilled to get an hole smaller then the dowel diameter. Then the parts have been fixed together and the dowel is introduced by rotational wood welding applying the Dowel at 1800 rounds/min within three seconds.