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Influence of the moisture content on flat-clinch connection of wood materials and aluminium

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ABSTRACT

The paper describes the joining of composites made of different types of wood-based materials and aluminium. The wood materials were conditioned in a climate chamber or in a chamber furnace to set specific moisture contents. Afterwards, the conditioned wood materials were joined with aluminium (Al 99.5) by means of flat-clinching. After a relaxation period of 48 h under standard climatic conditions the joint strengths at different moisture contents were quantified by cross tension tests. Based on the well-founded experimental studies the understanding of the flat-clinching technology for this kind of material combination was improved.

1. Introduction

The necessity of climate protection and resource conservation implies the need for innovative lightweight construction concepts. Such concepts can be achieved by the use of renewable materials combined with conventional light materials such as pure aluminium or aluminium alloys. Therefore, it is necessary to develop new joining technologies or to adapt existing technologies to the challenges of joining renewable materials with conventional materials.

In accordance with DIN 8593-0, joining describes a permanent connection of two or more parts; thereby, a local cohesion is created. For the joining of wood materials, there are several detachable and permanent connections. For the joining of wood materials, screwed, nailed and bolted connections are considered to be detachable, whereas the conglutination of two parts is a permanent connection. According to Wagenführ and Scholz (2008) wood is a natural product and is divided into hardwood and softwood. Wood materials are generally separated into solid wood, plywood, chipboard, fibreboard and composite materials. Fibreboards, such as medium density fibreboard (MDF) are produced by defibration and subsequent assembling of wood fibres (usually by using adhesives).

Despite the different advantages of conventional wood joining methods, these types of connections all have the same disadvantage. In all of these, auxiliary materials (e.g., adhesives, nails, screws, etc.) are required. In contrast, the mechanical joining of flat-clinching produces a form- and force-closed connection by selective plastic deformation of the joining partners. The forming of wood material represents a special challenge. Because of its orthotropic character, wood has different material properties in all three dimensions and only low material flow properties. Despite the limited ductility of wood, the objective is to produce wood products or hybrid wood components by flat-clinching.

2. Flat-clinching

Clinching is, in accordance with DIN 8593-5, assigned to the group 'joining by forming'. It is used to produce form- and force-closed connections by plastic deformation using a punch followed by spreading and compression in a die (see Fig. 1).

In conventional clinching, a connection occurs by a local forming process, where neither additives nor auxiliary materials are required. This attribute, the single-step process and long tool life characterize this method (Hahn et al., 1999; Kühne, 2000). One disadvantage of conventional clinch connections is the geometrical protrusion of the die-sided sheet metal, which is basically process-induced. Therefore, this kind of connection is not usable for visible and functional surfaces, e.g., for sliding parts and sealing bands.

Flat-clinching is a single-step, mechanical joining method that was developed and patented (DE 101 30 726 C 2) at the Technische

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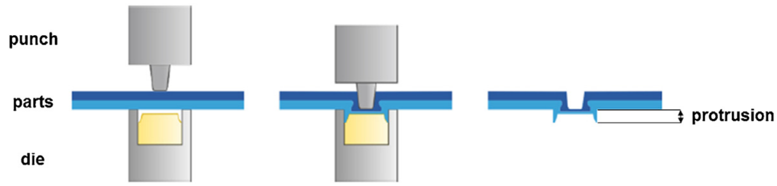

Fig. 1. Process of joining a conventional clinch connection (TOX, 2012).

Universität Chemnitz. Matthes et al. (2000, 2001) found out that the material flow that occurs during the forming process is influenced in such a way that allows the locking of the join partners. This results in a force- and form-closed interlocking within the total sheet thickness. In contrast to conventional clinch connections, a one sided planar connection is created that does not show the die-sided protrusion reaching out of the material plane (see Fig. 2). Because of its simple process, the flat-clinching method offers high efficiency.

The form- and force-closed interlocking, which is a characteristic feature of clinch connections, is shown in Fig. 3.

According to Beyer (2012) the most important variables of the flat-clinching process are the interlocking f, the neck thickness t_n, the bottom thickness t_b and the punch force F_{FS}. The Interlocking is an almost inseparable form- and force-closed connection between the join partners. Todtermuschke (2006) found out that the mechanical clamping is formed by the punch-sided material flow behind the anvil-sided material. This specific material flow in the bottom area occurs due to the avoidance of a die-sided protrusion by the anvil. In conventional clinching, the formation of the interlocking occurs by a material flow after passing out of the total sheet thickness.

Following flat-clinch connections of aluminium and wood materials are investigated. Therefore, it is necessary to characterize the used wood materials first.

3. Wood material

Wood is an orthotropic material. This means that, with regard to wood fibre, there are strong distinctions in longitudinal and radial direction. During the flat-clinching process, these different material characteristics influence interlocking in radial direction. The influence of the orthotropic material behaviour on the flat-clinch connection can be illustrated by the example of an aluminium–spruce-composite (see Fig. 4).

The irregular shape of the interlocking in the radial direction is caused by the orthotropic character of the wood material (see Fig. 4(a) and (b)). Therefore, the interlocking is insufficient for representing the quality of the whole connection. Thus, the separation force of cross tension tests is used for characterization of the joint strength.

Firstly, flat-clinch connections of plywood and aluminium, as well as fibreboard and aluminium were investigated. Based on the manufacturing of these two wood materials a quasi-isotropic and isotropic material behaviour was observed, respectively. The plywood materials were made of birch and poplar, respectively, which were laminated in multiple orthogonal layers. Despite the identical structure, the two types of wood had completely different mechanical properties. The class of fibreboard was represented by medium density fibreboard (MDF) and hardboard (HB). Based on the manufacturing of MDF and HB from non-orientated wood fibres, nearly isotropic material properties were assumed.

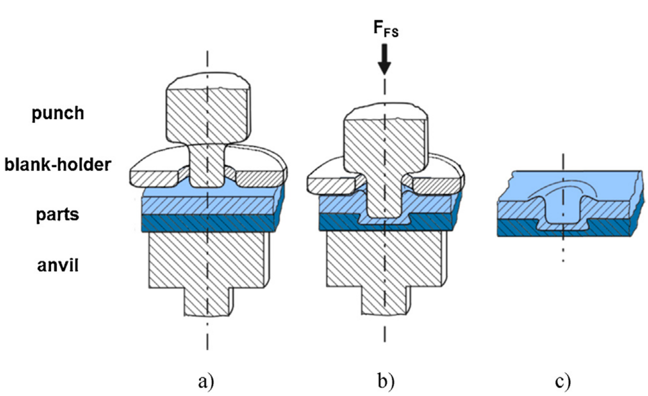

Fig. 2. Process of joining a flat-clinch connection. (a) Downstroke of blank-holder. (b) Penetration of punch owing to punch force F_{FS}. (c) Joined flat-clinch connection according to Todtermuschke (2006).

4. Experimental set-up and specimen preparation

Fig. 5 shows the experimental flow chart for investigating the influence of moisture content on the joint strength of the wood–aluminium composite.

4.1. Determination of the initial moisture content

At the outset the initial moisture content of the wood materials was determined. The measurement of the moisture content was performed with the moisture analyser DLB 160-3A (Kern), which operates according to the method of thermogravimetry.

According to DIN EN 13183-1, the moisture ω is defined as the ratio of the water mass m_w contained in the wood sample to a kiln-dried wood sample m_0 (anhydrous) in mass percentage, Eq. (1).

$$\omega\ (\%) = \frac{m_w}{m_0} \times 100 \quad (1)$$

Table 1 shows the measured initial moisture content of different wood materials.

4.2. Conditioning

Wood is a hygroscopic material that absorbs water from the environment by adsorption; it can also desorb water to the environment. Due to the hygroscopic nature of wood, the mechanical properties of wood-based materials depend on its moisture content. In order to verify the influence of the moisture content on the strength of the clinch connection, the joining was preceded by a conditioning process. Therefore, the KEYLWERTH Chart was used for the conditioning. The chart is based on the hygroscopic isotherm, which shows the dependence of the equilibrium moisture content of the temperature and of the humidity. The chart is

Table 1
Initial moisture content of different wood samples.

Wood material	Poplar plywood	Birch plywood	MDF	HB
Initial moisture content [%]	8.1	6.6	5.3	5.9