Production of structured thin wooden chips by milling with small cutting angles

Uwe Heisel; Johannes Tröger

Abstract:
Thin wooden chips can be used in a wide range, primarily to produce ecological positive materials to substitute plastics and mineral wool for the use of thermal isolation and packaging materials. There are wide resources of wood and it can be wasted ecologically. Additionally, the production of wooden chips for the above mentioned purposes has clear advantages regarding the expenditure of energy. With existing machining methods for the production of wooden cutting chips, only a chip thickness of more than .25 mm can be realized. By a new machining method with small tool rake angles, proper extremely thin and folded (structured) chips can be generated. The research emphasis is to study the parameters for generating these chips and their properties for thermal isolation and packaging purposes. First positive results show that this material can be the basis for a new wood material with an isolation property very closed to styro foam (PS).

Keywords: Production Process, Wood Chip Production, Thermal Isolation Material

Introduction

At the present intensive research is focusing an environmentally beneficial production technologies and the manufacturing of products not harmful to the environment. Some researchers, for example, propose the use of wooden milling chips or Miskantus gras for thermal isolation and packaging materials. The existing solutions show a high development-level [1, 2, 3].
German woodworking plants are usually organized as small to medium sized units. Therefore, a realization of the proposed solution [1] all over the country is hard to be carried out, because the sorted collecting and the required separation of chips and sawdust is a serious problem, especially concerning transportation facilities.
The industrial production of ecological isolation and packaging materials requires an industrial production of chips, too. Sufficient resources are available by nature in forestry at the present and in future. Light wood will always be supplied by the use of forests for wood production. Structured thin wooden chips can be used for the production of lightweight elements which show better filling properties in corners than thicker chips (h= 0.3 mm). These lightweight elements could be used for packaging forms. Sometimes, industrial produced waste of wooden milling chips of higher volume or especially curled chips of a thickness of 0.3 mm [4] are used in the USA for packaging purposes of hollow spaces. But at the moment, there is no way to produce form-stabilized shaped chips for packaging purposes or for thermal isolation materials, based on structured thin wooden chips.
Structured cutting chips could be used as well to substitute mineral wool (for example for tomato production, as a filling material in walls and roofs or for the production of flexible mattings). The production of isolation materials from mineral fibres (the stone material has to be melted and blown by air into fine fibres) requires a vast amount of energy has to be used (about 2,000 - 2,500 kWh/t). The substitution of wood fibre yields energy savings of about 450 kWh/t (estimated).

State of the art in wooden chip production

High quality chips for the industrial production of wood materials are industrially machined by the use of cutter disks or cutter blocks. The typical cylinder cutter block for contour milling can be shaped as shaft with blades on the outer contour or as hollow shaft with blades on the inner surface, where the cutting process takes place inside the hollow shaft. These cutting devices are called knife-ring flaker.
For the chip production for wood materials knife-shaft flakers or knife-ring flakers are widely used solutions, even if cutter disks produce chips at a higher quality level. Flat chips produced with the described methodare not to be used for isolation or packaging purposes because of their morphological characteristics.

Wood chip production with tapered milling tools

There is a wide range of possible wood machining processes to get form-stabilized materials for packaging purposes.

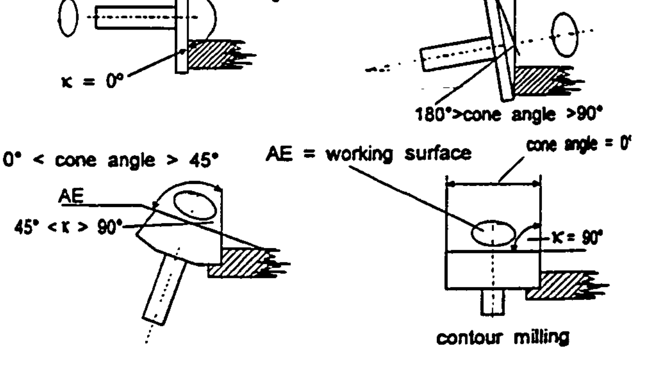

Fig. 1: Machining methods with tapered tools

This was the key to the development of a new method, which was first described by Lang [6]. He demonstrated that, a new method for the machining of wood caused by small angles between tool and workpiece, can be developed with new interesting effects with respect to of cutting quality. The tool is tilted towards the workpiece (figure 2).

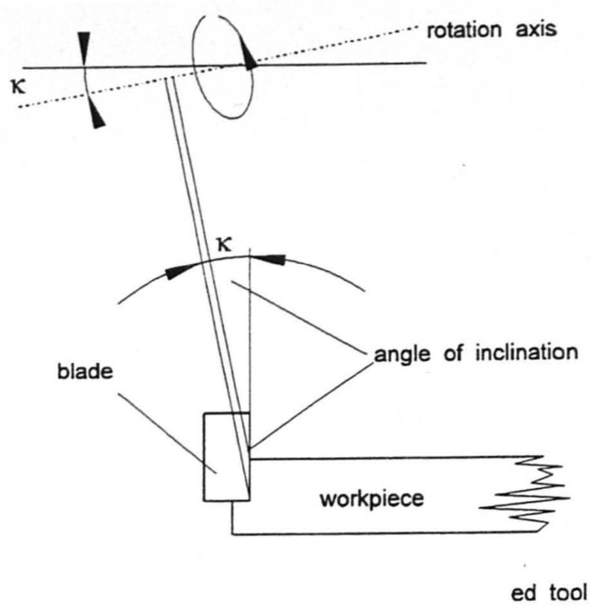

Fig. 2: Engaging principle of cutting blade

The angle between working surface (surface between cutting and feeding direction) and cutting surface is the angle of inclination (κ). This angle of inclination is manually responsible for the thickness of the chips. And this thickness of the chips directly represents the machining quality (reciprocal value of the size of an edge fault). For the thickness of the chips, the following relation is valid:

$$h(\phi,\kappa) = f_z \sin(\phi) \times \sin(\kappa) \quad (1)$$

with:

- z: number of teeth
- ϕ: cutting angle
- κ: angle of inclination
- h: chip thickness
- v_f: feed rate
- f_z: feed per tooth ($= v_f / n_z$)
- n: number of revolutions

By selecting an angle of inclination of for instance κ = 5° the chip thickness will be decreased to 9% regarding usual machining methods (for example compared to contour milling). Only extremely thin chips can be structured (folded) during the machining process.

The tapered tool produces a surface on the workpiece which can be described by the mathematical rules of a conic section. The geometry of the machined surface on the top of the workpiece can be described as a hyperbola [9]. The result of an approximation of this hyperbola by an arc of a circle is a circle with a diameter of 2 m, even if the diameter of the tool is only 220 mm. Looking on the surface of the workpiece, the result of this machining process is a cut free of waviness. That means, by the first time no cutting marks can be seen after the machining of wood [6]. Another result of this machining process are long and thin chips (figure 3).

To the influence of the angle of inclination

The angle of inclination (κ) is responsible for the geometry of the machined surface on the top of the workpiece. With κ = 0° the machined result on the surface will be a straight line [6]. By increasing angle of inclination, the geometry of the machined surface on the top of the workpiece will be curved more and more. First it describes a hyperbola, then a parabola to change into an ellipse and with κ = 90° it will be turning into a circle.

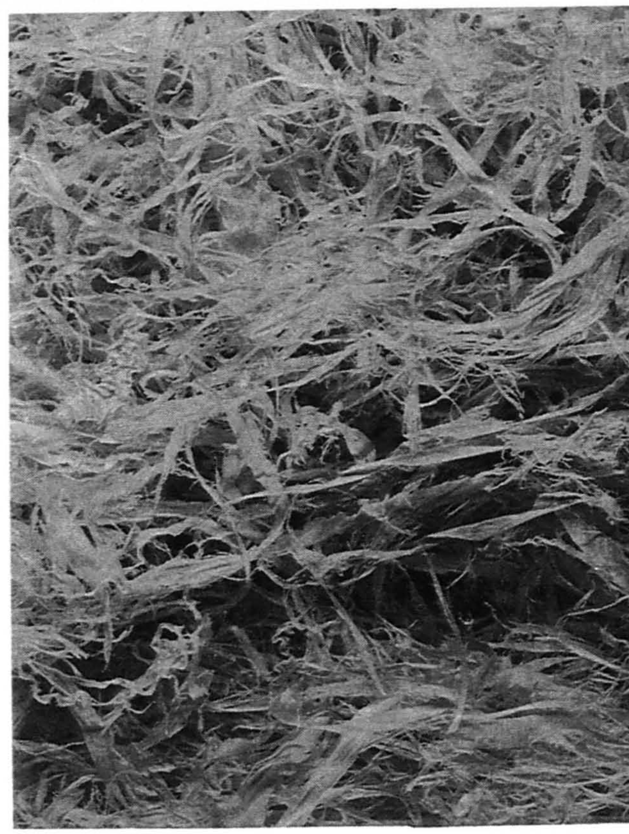

Fig. 3: Example of a typical chip geometry

First, the influence of the angle of inclination on the chip forming will be studied for beech and spruce. By an increasing angle of inclination a discontinuous chip will be formed. In the range of κ = 5°...8° flowing chip will be formed and the number of small or fine chips will decrease. By greater angles of inclination, a kind of discontinuous chip, sometimes curled, will be formed, as the one which results form contour milling (figure 4)

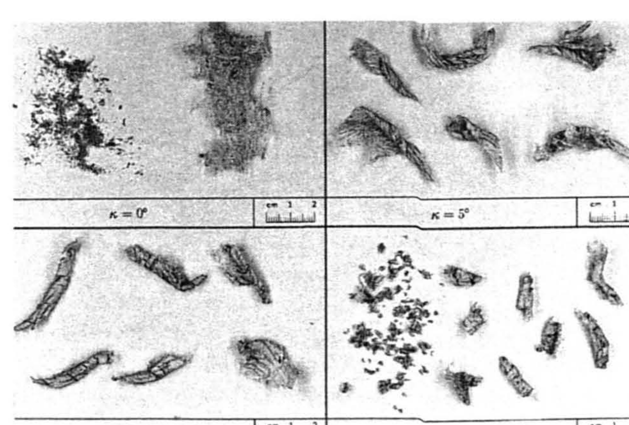

Fig. 4: Form of chips resulting by different angles of inclination (spruce)

The chip forming of beechwood is different from spruce. Basically, a similar length of the chip can be reached. But the chip of beechwood will be turned extremely during machining. Compared to sprucewood the chip becomes rather curled (fig. 5).

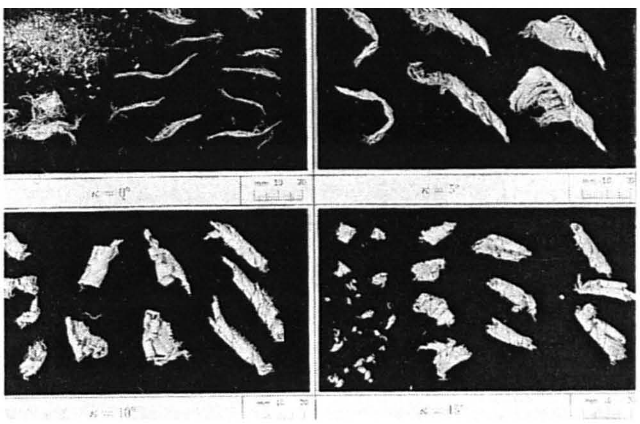

Fig. 5: Form of chips resulting by different angles of inclination (beech)

An other rather useful effect for the chip production and the machining quality is the result of the fact that the blade dives into the workpiece. This is the first time, that the cutting process is done by a drawing cut, which means that the blade is really drawn in longitudinal direction across the workpiece. Therefore the hollow moulding which usually appears (because of fields of different abrasiveness on the workpiece) during the milling process can not be found anymore.
Because of the longitudinal motion, the tool wedge angle in cutting direction (working cutting edge) can not be measured in direction perpendicular to the blade but at a slant angle. By that, the tool wedge angle becomes slim substantially. In relation to the workpiece, the blade is pushed across the surface, that means it dives into the workpiece. By actual experience the slight motion of the blade in longitudinal direction causes an increase of machining quality.

Description of different chip forms

Different chip forms can be produced due to different starting conditions with tapered tools. Besides the chip thickness, flat or curled and / or structured chips can be produced. According to preliminary examinations, the actual chip thickness refers to calculated values. Curled and / or structured chips could be used for thermal isolation or packaging purposes, where flat chips could be used for outer layers or as material for furniture production. The minimum chip thickness is about $h < 0.1$ mm which means it has the same thickness as industrially produced wooden boundles.
Figure 6 shows a twisted chip with a slight structure. By selecting the right processing parameters it is possible, to produce a twisted or curled chip with more or less distinguished structure on it (figure 7).
The machining allowance (engagement index a_c) plays an important role concerning the share of finest chips in milling with tapered tools. This is because starting at a certain machine allowance the peripheral part of the blade starts to cut.

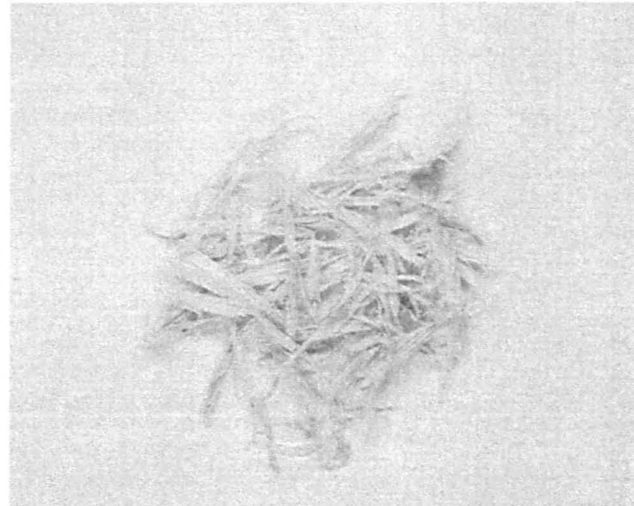

Fig. 6: Curled chip with a slight structure

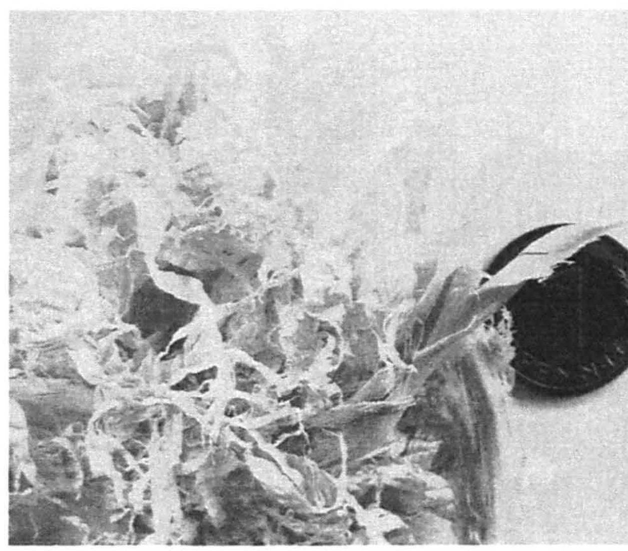

Fig. 7: Curled chip with a distinctive structure

The other possibility is to produce flat chips with a distinguished structure on it (figure 8).

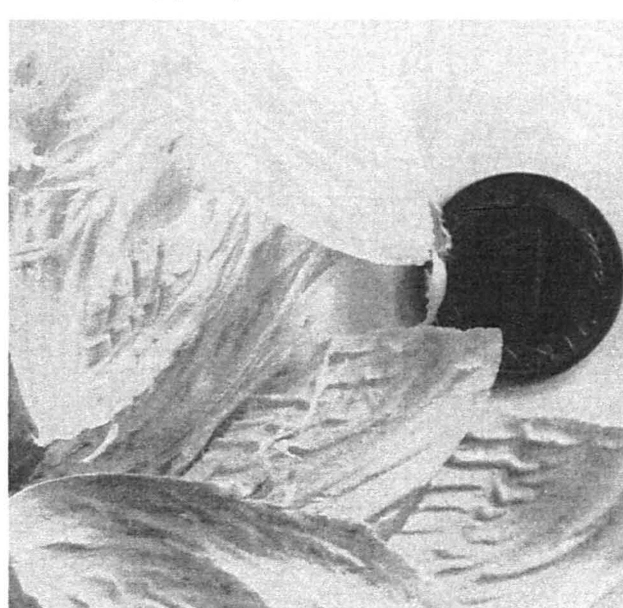

Fig. 8: Flat chip with a distinguished structure

The structure of a chip can be folded or flat. This can be determined by choosing the cutting parameters. Because of a higher elasticity, chips with a folded structure have a higher volume which improves the thermal isolation properties and similar shock absorbing capabilities. Systematic research on the origination of a chip depending on tool properties (especially the blade design) and the cutting parameters had not been done up to now. First samples of thermal isolation materials (figure 9) show properties which are very closed to the elasticity of styro foam (PS).

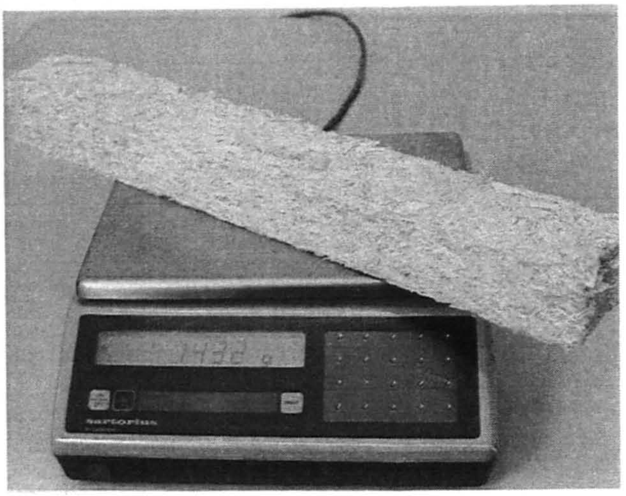

Fig. 9: Thermal isolation material made from structured wood chips

For the thermal conductivity a value of 0.055 W/m² was measured (styro foam (PS): 0.035...0.04 W/m²). This means that at 1.5 times of the thickness of a styro foam (PS) mat the material has the same thermal isolation capability and about the same of mineral wool mats. This rather good thermal isolation properties are reached by a porous low density.

Fig. 10: Cross section of the produced material

The porous structure can be seen clearly. Good shock absorbing capabilities (elasticity) and good thermal isolation properties (only few heat transfer transition) are to be expected because of a point contact.

Future prospects

Further investigations are to be done to find out how chips are formed. Therefor a laboratory chopper has to be realized. All important parameters, like rotational and feed speed, angle of inclination, number of tools, tool geometry and material, angle of chip breaker and design of enveloping of chips should be adjustable.

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