Proceedings of the

International Panel Products Symposium 2015

joint conference with

COST Action FP1303

Performance of bio-based building materials

Llandudno, Wales, UK

7-8 October 2015

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Copies available from
The BioComposites Centre,
Bangor University, Deiniol Road, Bangor, Gwynedd LL57 2UW, UK
www.bc.bangor.ac.uk

ISBN: 978-1-84220-136-7

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PREFACE

Rob Elias

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It is with great pleasure that I welcome you back to Llandudno for IPPS 2015. This year we have joined forces with COST ACTION FP1303. This COST Action focusses on the issues of durability, performance and service life of bio-based products, and therefore provides an important drive for future product development. I hope this will provide extra breadth to discussions, and potential new networks formed during the event.

In 2015 the EU has seen a growing demand for housing whilst facing some shifting challenges. A reduction in skilled workers in the construction industry is increasing the drive for off-site and prefabrication technologies. This, in combination with the need to improve thermal efficiency of buildings, is pushing the demand for new products.

Industry and academia must work closely together to face these challenges. The training of engineers and material specialists to help equip the workforce for the future is an important area for collaboration. Research is needed to increase the use of wood based panels in pre-fabrication applications. Material engineers and wood scientists who have an understanding of how wood and natural fibre products perform will be needed to address these challenges and improve utilisation and resource efficiency in service not only during production and installation.

Another challenge for our sector is to improve the way we disseminate and exploit the economic and environmental impact of our industry. To achieve this we need to consider better ways of communicating the benefits of using wood based panel products in construction from a social, environmental and economic perspective. The use of different media to get our message over is important, and events such as IPPS can play a role by engaging with industry, journalists and academic stakeholders.

Finally I would like to thank all our speakers, sponsors, delegates and staff for all the hard work that is needed to bring IPPS together. I hope you find the papers and presentations of interest and I look forward to your continuing support.

FOREWORD

Dennis Jones

Chair, COST Action FP1303
SP Technical Research Institute of Sweden, Stockholm, Sweden

The International Panel Products Symposium (IPPS) has for some years been established as the key conference and networking portal for the panel products and composites sector, bringing together academics and industry to discuss the latest developments in product design and manufacture and allowing discussions on the important topics to maintain and expand the impact of the industry on the international consumer market. This year's conference features a link with the COST Action FP1303 ("Performance of biobased building materials"). Recent market developments have seen an increased demand for bio-based products, with a greater understanding of the environmental impact of modern materials and today's society.

In order to help deliver products meeting these ever changing and increasingly stringent demands from consumers, it is essential for industry to collaborate closely with academia. Such interactions are strongly promoted by the European Cooperation in Science and Technology (COST) networks. COST Actions have frequently been the precursors for successful projects in the EU Framework Programme, and will continue to provide platforms for Horizon 2020 proposals. Furthermore, COST Actions foster scientific excellence throughout Europe and have a societal impact in their contribution to knowledge, to its wider dissemination to policy makers and the public at large and to the tackling of problems deriving from urging societal needs.

COST is not a new concept – it has been around since 1971. COST was and still is the first and widest European framework for the transnational coordination of nationally funded research activities. It is based on an inter-governmental agreement and comprises currently 36 European Member Countries plus one Cooperating State (Israel).Indeed the panel products sector has benefitted from its interaction with COST in the past, through COST Action E49 "Processes and Performance of Wood-based Panels", as well as relevant activities in other Actions dealing with wood treatments and adhesive performance.

COST Action FP1303, as its name suggests, focusses on the demand from end-users for products with enhanced service lives and performance in service. Meting these consumer demands is key for the panel products industry to maintain and grow their business. General performance and specific issues over indoor air quality, durability and moisture stability are issues where industry can adopt techniques and treatments being developed by academia.

This joint IPPS 2015 COST Action FP1303 conference sees a blend of presentations with industrial application as well as innovative research. The friendly atmosphere generated by the venue and the members of the Biocomposites Centre will allow delegates from all sectors to discuss ideas and needs, hopefully helping build new collaborative links. The desire to engage industry is an essential goal with the COST organization.

On behalf of COST Action FP1303, I hope you find this joint conference interesting and stimulating, with it providing new links and opportunities.

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EFFECTS OF REFINING PARAMETERS ON FIBRE QUALITY MEASURED BY FIBRE CUBE

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SUMMARY

Fibre quality and fibre size distribution are important parameters for MDF production control. Sophisticated and automated systems are not available on the market so far, in order to meet the requirements for a sufficient testing device. In this paper a newly developed system is presented: FibreCube. This device enables the measurement of fibres, esp. for fibreboard production, with a suitable resolution, testing speed, and data evaluation. With this method it is possible to analyse the effect of process parameters (i.e. wood species, refiner disc gap) on the fibre size characteristics.
In this paper it is shown that the effect of wood species and process parameters on the fibre quality can be clearly differentiated: Pine wood fibres show a quite even distribution of fibre length with a mean slightly lower than 3 mm. The proportion of short fibres is relatively small. Beech wood fibres show a much higher content of short fibres with a mean at about 1 mm. With an increased refiner disc gap the distributions changes clearly; the mean is shifted to a higher fibre length, the amount of shorter fibre decreases, and the number of longer fibres (i.e. shives) increases. Finally, the content of fine fibres is higher for moulding grade MDF than MDF than HDF. Simultaneously, the content of larger fibres is higher for HDF than MDF than moulding grade MDF.
These findings indicate the potential of an adequate measuring system for MDF industrial production, which facilitates the detection of changes in the defibration process, as a consequence of changes in fibre quality, and predicts changes in panel properties before pressing. In summary, fibre characterization is an advantageous tool for process control.

INTRODUCTION

In the wood-based panel industry, the size distribution and morphology of the wood particles, respectively wood fibres, is of importance for production and the resulting panel properties. Despite the importance of fibre quality for medium-density fibreboard (MDF) production, its evaluation continues to be done on a low technical level because no adequate measuring devices are available in the market. This is the result of a worldwide survey of MDF factories, presented at the "International Wood Composites Symposium" (IWCS) in Seattle, Washington/USA (Benthien et al., 2013). According to the results of this study, skilled personnel perform the great majority of fibre quality control with haptical and visual evaluation. Furthermore, fibre quality is evaluated by various sieving methods adapted from particleboard production, comparing the actually produced surface with MDF reference samples, as well as on basis of the fibre mat density. Image-based fibre analysis systems from the pulp and paper industry cannot be established adequately for the characterization of thermo mechanical pulp (TMP). Because of the large size spectrum of TMP - the particle size ranges from small dust particles (fibre fragments), to individual wood fibres, up to several-centimetre-sized fibre bundles (undefibrated wood particles) - such systems are inapplicable for TMP characterization. In particular, fibre bundles (shives) tend to block the flow-cell, as our own experiments applying a "Kajaani Fiber Lab" (Metso Automation, Kajaani, Finland) have shown.

The limited usability of wet-fibre suspension-based image analysis techniques for the characterization of TMP also applies for dry-image fibre analysis systems. In particular the need to separate the fibres before image acquisition with manual and time-consuming techniques, as well as the need to sort-out overlapped imaged fibres are limitations of otherwise promising measuring systems e.g. FibreShape (IST - Innovative Sintering Technologies Ltd., Vilters, Schweiz), the QIC-PIC (Sympatec GmbH, Clausthal-Zellerfeld, Deutschland) and the Camsizer (Retsch, Haan, Deutschland).

This determined our motivation to overcome the limitations of currently available measuring systems. It was our aim to develop a software and hardware in order to optimise wood fibre size measurement: The hardware should be easy to use, process dry fibres, separate fibres and agglomerates, disperse fibres in air, and have a suitable image acquisition system; the software should be able to identify and separate overlapping fibres in the images.

The technical set-up of the measuring device hardware component can be roughly partitioned into three sections: mechanical fibre separation, image acquisition, and cleaning (Figure 1). The mechanical fibre separation is arranged by means of specially tuned airflows, and completes when the fibres land as a fine scattered film on the continuously rotating glass plate, which can be considered as the objective plate. Passing the photo unit, the fibres are imaged with an industrial high-resolution grey scale.

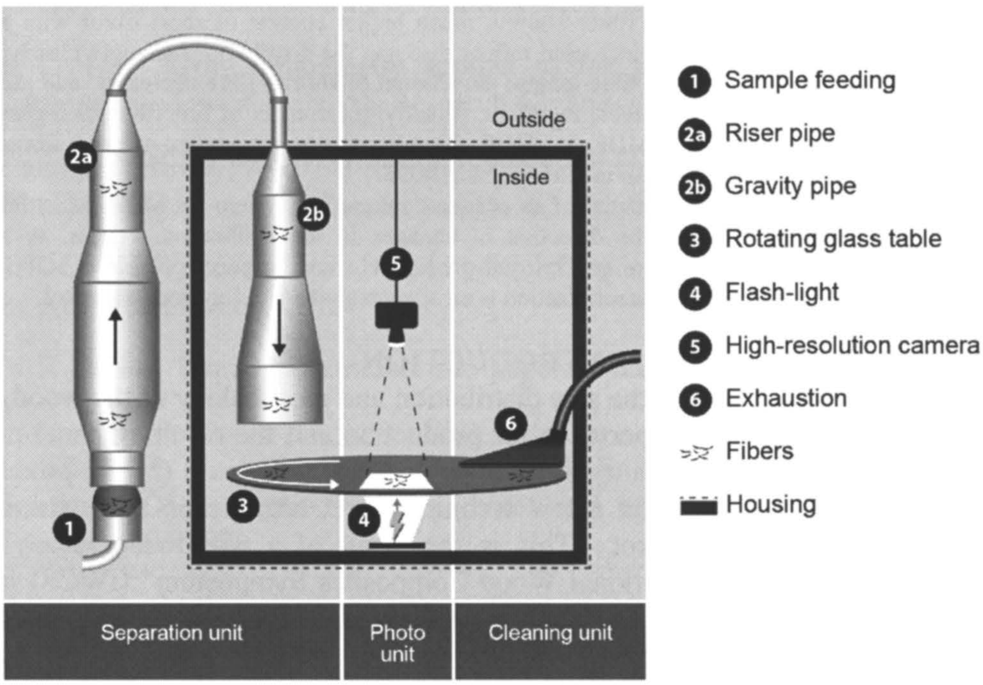

Figure 1: Diagram of the experimental setup of FibreCube.

The image-analysis software, which was developed for this particular purpose facilitates two different methods in order to measure fibre-size in a sub-pixel accuracy and to separate possibly overlapping fibres: *fibre-tracing* and *image moment* method. This enables determination and calculation various fibre characteristics, i.e. fibre length, width and slenderness ratio as well as relative fibre number, some fineness characteristics and shive content.

With this method, we call FibreCube it is possible to analyse the effect of the refining process on the fibre size characteristics, i.e. wood species, refiner disc gap, and others, which will be given in this paper.

MATERIALS AND METHODS

METHODOLOGY

The technical setup of the recently developed particle analysing system is shown in Figure 1. Within this schematic drawing the particle analysis system is partitioned into three sections: (a) dispersion unit, (b) photo unit and (c) cleaning unit. In the dispersion unit a fibre sample (approximately 0.5 g) is applied into the lower opening of the riser pipe (2a) by a sample-feeding device (1). Fibre separation and transport through the pipe system is by compressed air. Altering the airflow velocity within the pipe system and varying pipe diameters assists fibre separation. When reaching the gravity pipe (2b), fibres descend in the slowing airflow to the rotating glass table (3). Within the darkened chamber the fibres are continuously transported to the photo unit by the rotating glass table. The photo unit consists of a strobe light (4) and a high-resolution camera (5). The strobe light is transmitted from the opposite side of the camera so pictures are taken by transmitted light technology. With a frequency of approximately 82 pictures per minute fibres are photographed which result in approximately 560 pictures per measuring cycle. The cleaning unit contains a vacuum extraction system (6) to remove the fibres from the glass table.

The optical resolution of the camera (GE4000, Allied Vision Technologies GmbH, Stadtroda, Germany) used within the particle analyser was stated to be 4008 x 2672 pixel (nominal 11 megapixel). In order to determine the size of the recorded glass table area (aspect ratio 1.5:1) and the effective pixel edge length, an object micrometer (Objektmikrometer 3, POG Präzisionsoptik Gera GmbH, Gera, Germany) was placed on the glass table and photographed. It was found that 10 mm at the object micrometre corresponded to 430 pixels within the image. Based on these values, the effective edge length of the quadratic pixels was calculated to be 23.2 μm, the photographed area of the glass table to be approximately 93 mm x 62 mm, and the picture resolution to 1095 dpi (dots per inch), respectively, pixel per inch (ppi).
During image analysis (flow line tracing) the resolution is technically increased due to highly accurate sub pixel fibre extracting: by switching from the pixel grid to a continuous representation of the image using B-spline interpolation the resolution is much more precise than the optical resolution.

The obtained grey scale images from the particle analysing system's photo unit are analysed according to one of three methods: (1) flow line tracing or (2) image moment method. At first, an attempt is made to apply flow line tracing. Subsequently, if this method cannot be applied to measure the length of the detected object, an attempt is made to apply image moment.

Before the software starts to determine the fibre dimensions, the image is pre-processed for further analysis by possible inversion, image calibration and selection of an adequate threshold value to define which shade of grey should be assigned as fibre, respectively background. Image calibration is necessary for reducing the influence of the flash and small contaminations of the glass plate. This is done by taking several images of the rotating glass plate without fibres and forming a mean image, which is subtracted from each image during actual image acquisition. Further on, the image is partitioned into several regions of interest by connecting neighbouring fibre pixels. These regions form the basis for further analysis. Each of them contains several possible fibres and is processed separately afterwards using the aforementioned three methods. Ohlmeyer et al. (2011a; 2011b) and Pieper et al. (2011) presented previous levels of software developments (Segmenter Software).

The result of image analysis is a table of fibre statistics, which are then exported to a CSV-File for further analysis.

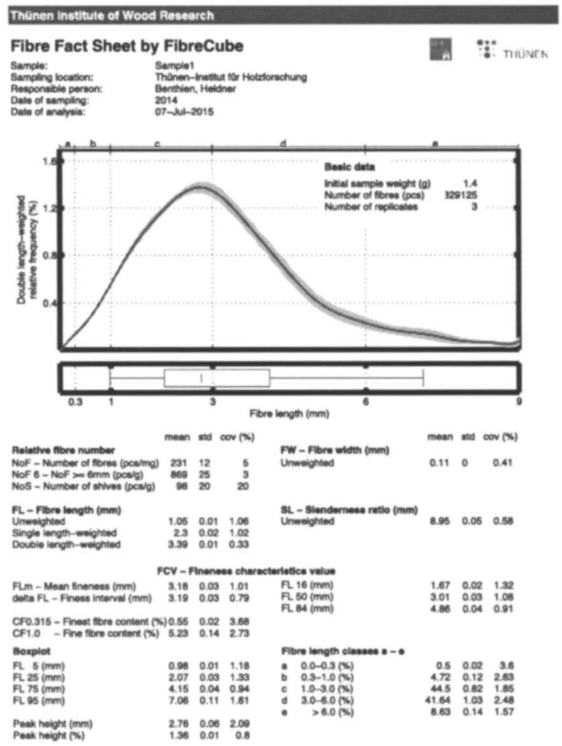

Figure 2: Example for a FibreFactSheet.

In this approach images of fibres are interpreted as relief maps with dark image values corresponding to high evaluation points and bright points corresponding to flat ones. Fibres can then be imagined to be mountains on an otherwise flat landscape. In case of flow-line tracing and, with this model in mind, fibre extraction, the process comprises wandering on ridges from mountain peak to mountain peak. The result of this process is a network of walkways each representing a skeleton-like part of a fibre. Based on this network, an algorithm separates overlapping fibres and detects branching.

The flow-line tracing algorithm is based on the so-called exact watershed transformation from Meine and Köthe (2005). With small modifications it can be used for highly accurate sub pixel extraction of fibres. This is possible by switching from the pixel grid to a continuous representation of the image using B-spline interpolation. They can be computed very quickly with recursive linear filters (Unser et al., 1993).

Each detected and length measured fibre was assigned into one of 656 length classes (width of each class is 0.05 mm) by a special analysis tool. As a final output of this tool, the number of fibres, the arithmetic fibre length, the mean value of the squared fibre length (l^2) and the mean value of the cubed fibre length (l^3) are provided for each length class. Based on this data, the double

Summary of the FibreCube characteristics:

- sampling of dry fibres
- characterisation of the entire fibre size range
- approx. 0.5 g of fibres per one sample
- about 560 images with > 250.000 fibres
- image size: 93 x 62 mm^2
- resolution: 1095 dpi
- pixel size: 23.2 µm
- data acquisition: < 8 min per run
- evaluation of data: 3 - 5 min

length-weighted relative frequency was calculated and used for line chart creation. The double length-weighted fibre length (L_w) for each fibre type was calculated in accordance with Robertson et al. (1999) ($L_w = \sum n \cdot l^3 / \sum n \cdot l^2$). Benthien at al. (2014) provide more detailed information on the technology of FibreCube.

Based on these calculations a number of key figures are determined and summarised in the so-called FibreFactSheet, which is given as an example in Figure 2. These figures may be used for an individual analysis of various kinds of fibres.

MATERIAL

Effect of wood specie on fibre length

Chips from various wood assortments were processed with same conditions using a laboratory refiner: They ware steamed at 170 °C for 4 minutes. The refiner disc gap was kept constant at 0.15 mm. As raw material for the thermo-mechanical refining process, Scots pine (*Pinus sylvestris*) and Beech (*Fagus sylvatica*) wood chips were used. Additionally, a mixture of Pine and Beech chips were refined with same parameters; the share was 50:50 by weight. Subsequently to the refining process, the fibres were dried by a flash tube dryer and collected for further analysis with the FibreCube.

Effect of refiner disc gap on fibre length

Scots pine (*Pinus sylvestris*) wood chips were processed using a laboratory refiner with steaming pressure 6 bar for 5 minutes and various refiner disc gaps between 0.1 and 1.0 mm. Subsequently to the refining process, the fibres were dried by a flash tube dryer and collected for further analysis with the FibreCube.

Fibre Length for various industrial products

In order to assess the fibre length for various industrial products the results from industrial tests of fibres for different products (i.e. MDF, HDF, and moulding grade MDF) were compared: The fibres and data were obtained from the regular production at a German MDF site during a 100-day test period of the FibreCube in the site's laboratory.

RESULTS AND DISCUSSION

Effect of wood specie on fibre length

Figure 3 presents the fibre length distribution represented as a double length-weighted frequency for fibres processed from beech wood chips, pine wood chips, a 50:50 per cent ratio of beech and pine wood chips, as well as a combined calculation of the results from original beech and pine wood chips.

Due to the same process conditions the fibres of beech and pine have significant difference in fibre length distribution: Pine wood fibres show a quite even distribution of fibre length with a mean little lower than 3 mm. The share of short fibres is relatively small. Beech wood fibres show a much higher content of short fibres with a mean at about 1 mm; the frequency of longer fibres is much less than for pine fibres.

The fibres processed from a 50:50 % mixture of beech and pine wood chips have a much broader fibre size distribution, covering a main range from 1 to nearly 3 mm of fibre length. To prove the reliability of the data the original data of beech and pine fibres were calculated at the same time with the same statistical procedure; the fibre size distribution (Pine + Beech) was more or less the same as the 50:50 % mixture of processed fibres.

With the FibreCube system a clear differentiation of fibres processed from various wood species is possible.

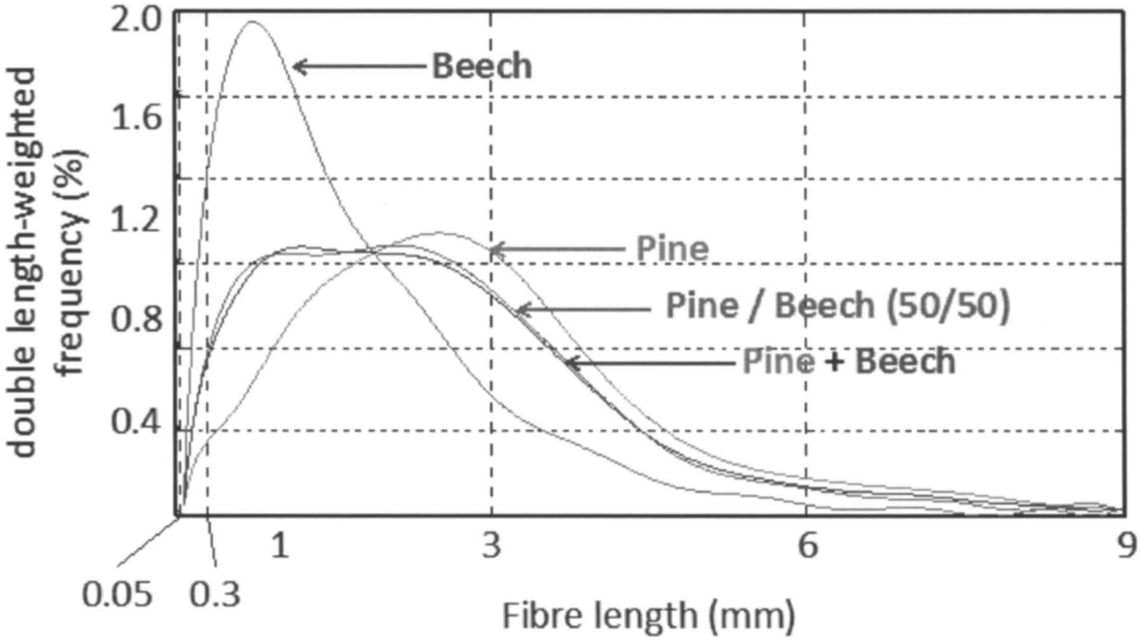

Figure 3: Double length-weighted frequency of fibre length; fibres made of beech and pine wood chips with steaming pressure at 170 °C and time 4 minutes and refiner disc gap 0,15 mm

Effect of refiner disc gap on fibre length

In figure 4 the effect of refiner disc gap on fibre length is shown: While the fibre size distribution of a 0.1 mm refiner disc gap is quite similar to the pine fibres in figure 3, the distributions changes clearly with an increased disc gap. The mean is shifted to a higher fibre length, the amount of shorter fibre decreases, and the number of longer fibres (ie. shives) increases. In principle, this meets the common idea of the effect of refiner disc gap on the fibre geometry.

Consequently, with the FibreCube system a clear differentiation of fibres processed with different process conditions is possible.

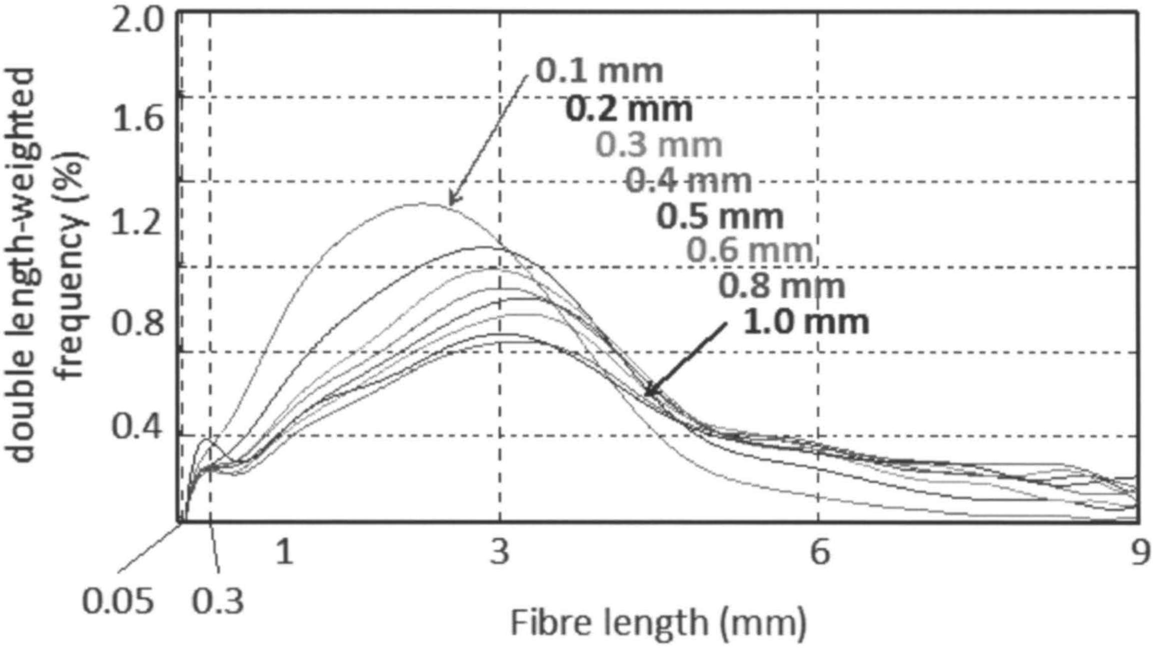

Figure 4: Double length-weighted frequency of fibre length; fibres made of pine wood chips with steaming pressure 6 bar and time 5 minutes and various refiner disc gaps between 0,1 and 1,0 mm

Fibre Length compared with process parameters

Figure 5 delivers the comparison of the double length-weighted fibre length for different industrial products (MDF, HDF, moulding grade MDF). The individual products have different requirements regarding fibre quality, which is affected by the raw material and the process parameters applied.

It can be clearly seen that the content of smaller / fine fibres is higher for moulding grade MDF than MDF or HDF. Simultaneously, the content of larger fibres is higher for HDF than MDF or moulding grade MDF. These observations match the requirements of the different products: For moulding grade MDF fine fibres are typically used in order to avoid pull outs during moulding the panels and to reduce the defects on the moulded surface. For HDF the quality of fibres is less important, therefore, a larger refiner disc gap may be used which leads in lower specific refiner energy consumption and larger fibres.

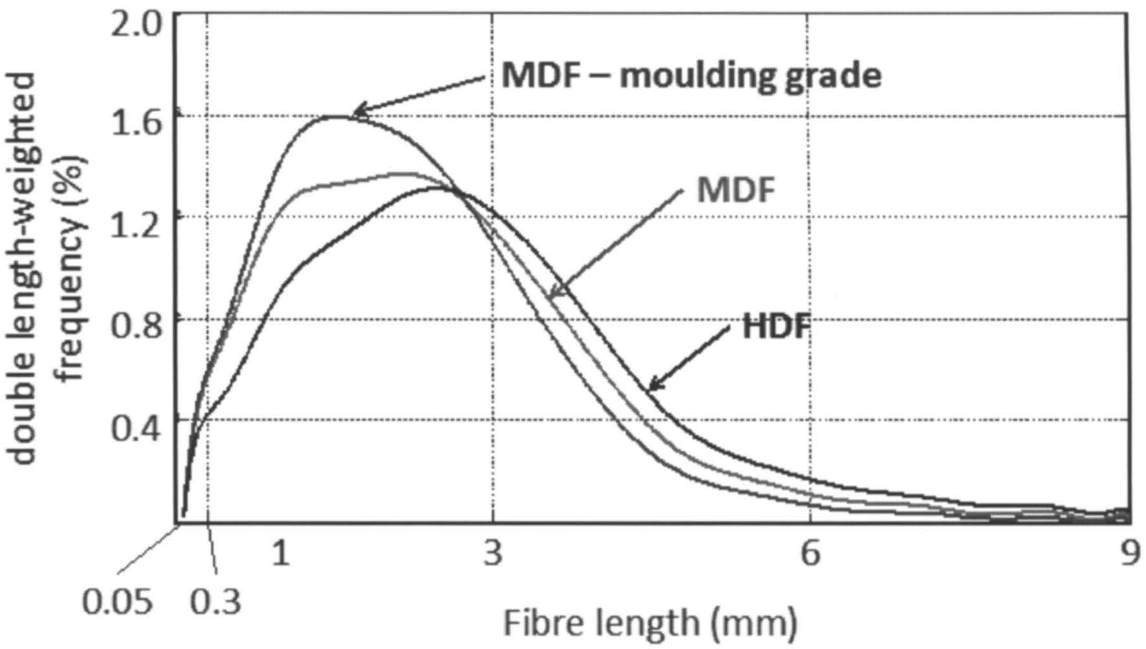

Figure 5: Double length-weighted fibre length of fibres for various industrial products.

CONCLUSIONS

Although particle size distribution and morphology are important factors for MDF production, fibre quality control is measured with low technical accuracy because adequate measurement systems are not available. Within this paper a recently developed particle analysis system was presented, and used for the characterization of different fibre types manufactured under varying conditions in the thermo-mechanical defibration process. With the aim of verifying the effects of wood species and different defibration conditions the fibre size distribution was determined using this technique.

Using this method it is evident that the measurement of MDF fibre particle size distribution is possible: small and large sized fibres can be detected without causing a blockage of the system, the number of measured fibres is high, the measuring process is fast and automated. It is therefore concluded that

- FibreCube is a suitable new method to measure fibre size distribution.
- The system is able to measure minimum 250k fibres in less than 10 minutes with a resolution of 23.2 µm.
- The results clearly indicate the effect of refining parameters on the fibre size distribution as well as their influence on panel properties.
- The potential for further research under laboratory and industrial conditions can be demonstrated.

The experiments have shown a clear effect of raw material wood species as well as selected fibre manufacturing conditions on resulting fibre quality. Furthermore, the fibre size was compared for different industrial products: different fibre length values were determined for MDF, moulding grade MDF, and HDF.

These findings demonstrate the potential of the system as an adequate measuring system for MDF industrial production, which facilitates the detection of changes in the defibration process, as a consequence of changes in fibre quality. Therefore the opportunity to predict changes in panel properties using such a technique will be possible in the future. In summary, fibre characterization is an advantageous tool for process control.

ACKNOWLEDGEMENT

The financial support of Fachagentur Nachwachsende Rohstoffe e.V. (FNR) on behalf of the Federal Ministry of Food and Agriculture (BMEL) and Aif Projekt GmbH on behalf of the Federal Ministry of Economics and Technology (BMWi) is gratefully acknowledged.

We also would like to thank our project partners for their contribution: Fagus-GreCon Greten GmbH & Co. KG (GreCon) (Alfeld, Germany), Glunz AG (Meppen, Germany), Andritz AG (Graz, Österreich), Institut für Holztechnologie Dresden (IHD) (Dresden, Germany).

The authors would like to acknowledge support from COST Action FP1303 to attend the joint IPPS 2015/COST Action FP1303 conference to present this work.

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