# The Micro-Mechanical Characterization of Wood Fibers: A strategy for distinguishing between early and late wood growth.

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**Abstract.** Wood fibers are of the order of a few millimeters in length and a hundred micrometers in width, which makes it difficult to mechanically characterize them using standard methods, such as tensile testing. This work, builds on the development of a novel method to evaluate the stiffness of wood fibers, which uses the cantilever of an atomic force microscope (AFM) to carry out three-point bending. This is done by placing the fibers across a two millimeter trench, whereupon the AFM engages to the center and both applies loads and records the resulting displacements. Testing using this method has been confined to a single species of wood, *pinus sylvestris* (Scots pine), but there is a significant spread in the modulus of the fibres tested. This is not entirely surprising as a sample of wood consists of several different types of fibre, including, for example, heartwood and sapwood, early wood and latewood. These different fibres vary slightly in size and wall thickness.

Here, Weibull statistics is used to investigate the correlation between samples in a dataset, and describe the magnitude of the correlation, in order to distinguish between fibre types and to provide greater clarity of the modulus associated with different types of fibre.

## Introduction

Timber is a composite material ordered over many length scales. The basic building blocks of timber are wood fibers: hollow, tube-like elements which are responsible for both water transport and load bearing within trees [1]. The fibers can be separated from bulk timber in a process known as defibrillation, a key industrial process for the production of medium density fiberboard (MDF). MDF is a composite material formed of wood fibers and adhesives, which is used widely in the construction industry amongst others. These wood fibers are generally a few millimeters in length, and are around seventy micrometers in width; there is some variation in wall thickness and overall size, depending on whether the fibre is early or late growth, heart or sap wood, and a number of other factors. They are often twisted, frayed, and irregularly curved. Whilst attempts have been made to test these fibres using conventional mechanical testing, the geometries of these fibres render such testing problematic. In this work a novel method to mechanically characterize wood fibers has been developed: three-point-bending of a fibre is carried out using the cantilever of an atomic force microscope to load fibers that have been placed across a purpose built testing rig [5].

## Methods

The atomic force microscope is an extremely versatile tool most commonly used in the field of surface analysis. It is regularly applied to investigate of surface topography and roughness [3]. The AFM's applicability to the nano scale has allowed investigations of many materials including nano-wires, cellulose nano-fibrils, and carbon fibers, among others [2, 4]. In this work, the AFM has been used to mechanically characterize wood fibers, as described in the literature [5], see Figure 1.

In initial work, the modulus was extracted from force-displacement data by considering the fiber to be an extruded annulus in elastic bending [5], which is not entirely correct [6]. The model is being revised on the basis of a typical wood fiber; considering the variability in diameter and wall thickness [7]. The system is additionally complicated by the fact that the fiber is (a) not solid, and (b) can vary in conformation depending upon a number of variables for example whether the wood fibers are from early or late growth.

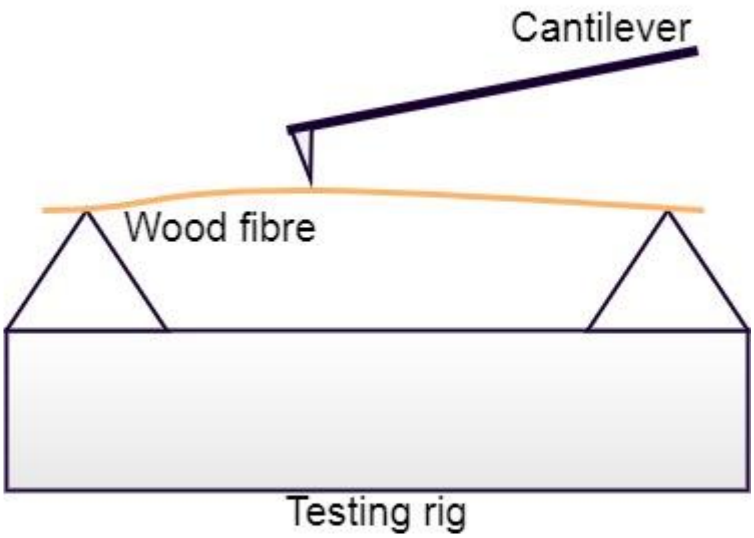

Figure 1: The testing schematic for the three-point-bend testing of wood fibers using AFM. A stainless steel rig, with two knife edges two millimeters apart, supports a single wood fibre. After measuring the dimensions of the fibers, the AFM engages with the centre of the fibre: the load is applied here and the resulting displacement measured.

## Analysis

Whilst the method has been shown to be effective [5], the spread observed in the modulus measured for a randomly selected group of fibres is quite large, although this is not unexpected given the nature of the fibres. Not only is there inherent variability from fibre to fibre, which is larger than would be found in manufactured parts, but a selection of fibres will contain examples from different kinds of growth, and hence which have different morphologies. Chemical information has been used to distinguish between these fibres [8], but this is not practicable in the current work. Weibull statistics, is widely used as a tool for understanding the behavior of materials, particularly when I data set might include two (or more) distinct families relating to an identifiable feature. Wood fibers present an interesting candidate for Weibull analysis and the current work considers its application to modulus measurements in order to distinguish between e.g. heartwood versus sapwood, early wood versus latewood.

## Concluding Remarks

The mechanical characterization of wood fibers will be informative of the relative strengths/stiffness's of fibers by type. On this basis it will be possible to assess the impact of various adhesives, resins, and other chemical treatments on the mechanical properties of the wood fiber and the subsequent products produced from them.

## References

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