Dynamic Young's modulus and glass transition temperature of selected tropical wood species

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Dynamic Young's modulus (E_d) of selected tropical wood species, namely Dyera polyphylla, Endospermum diadenum, Cratoxylum arborecens, Alstonia pneumatophora, Macaranga gigantea and Commersonia bartramia, used for the study was measured using the free–free flexural vibration method. Young's modulus from three point bending (E_{3pb}) and compression parallel to grain (E_{cp}) was also studied. The results show that the relationship between E_d and E_{3pb} for all wood species is very significant with the mean value of E_d consistently larger than or sometime equal to E_{3pb}. Surprisingly, the relationship between E_d and E_{cp} is not significant except for Alstonia pneumatophora. The dynamic mechanical thermal properties were also investigated using the dynamic mechanical thermal analyser (DMTA). The results showed that the storage modulus of the wood species at −90°C is in the range of 1·48–4·09 GPa with a glass transition temperature ranging from 50 to 70°C.

Keywords: Dynamic Young's modulus, Glass transition temperature, Three point bending Young's modulus, Compressive Young's modulus, Storage modulus, Loss tangent

Introduction

The vibration technique is one of non-destructive testing (NDT) techniques which is considered important in the timber industry.[1] This technique is an alternative for measuring the elastic properties and energy dissipation of wood. The method involves three types of vibration, namely bending (flexural), longitudinal (axial) and torsion which are determined by the nature of vibration.[2,3] Among the three types of vibrational methods, the flexural vibration method is more popular since it is easier to excite and detect vibrations under investigation.

In 1958, the free–free flexural vibration method was introduced by Haermon to investigate the E_d of wood. Several studies had showed a good relationship between the E_d and static Young's modulus (E_s) obtained from quasi-static tests.[3–6] Young's modulus from vibration was consistently larger than those obtained from quasi-static tests. Generally E_d was in the range of 5–10% higher than E_s.[3] Llic[5] also found that E_d was larger than E_{3pb} and the correlation coefficient between E_d and E_{3pb} was 0·99. Divos and Tanaka[6] reported that E_d for non-tropical wood was 10 and 6·5% larger than E_{3pb} when tested at 0·1 and 10 mm min^{-1} respectively. Duju and Nakai[7,8] have studied the mechanical properties of the tropical wood species namely Cotylelobium burckii, Dipterocarpus rigidus and Acacia mangium by using the longitudinal vibration frequency and static test. Although the free–free flexural vibration method has been used for over 50 years, the application of this method to the Malaysian tropical wood is still new. This situation led to the hypothesis that the use of the free–free flexural vibration method may be useful in predicting the elastic properties of several selected tropical wood species.

Wood is a viscoelastic material that exists typically in two distinct states. They may exhibit the properties of glass (high modulus) at low temperatures and rubber (low modulus) at higher temperatures. By scanning the temperature during the experiment, the glass transition could be observed.[9,10] Many studies have been carried out on dynamic mechanical thermal properties of wood and composite wood.[11–15] However, only few researches had been conducted on tropical wood species.

The dynamic mechanical thermal analyser (DMTA) is applied to the study of the effect of the storage modulus (logE') and loss tangent (tan δ) of wood with temperature. With the DMTA in mechanical tests, molecules in wood interact with mechanical stress. Normally, all molecular relaxation processes are detected by use of this technique. Data from the DMTA are displayed as graphs of logE' and tan δ versus temperature. From the data, the changes in logE' gave various states of molecular motion, for example, molecular relaxation at the glass transition temperature (T_g) and secondary molecular relaxation can also be measured quantitatively as the temperature is scanned.

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