Research and Development of Wood/Plastic Composite Materials (II) Dynamic Viscoelasticities of Three Types of Wood Fibre/PP Composites, Spruce Wood and Particleboard

W. T. Peng [1], Yan-san Huang [2] and Yuh-shiow Chen [2]

[Summary]

The purpose of this study was intended to investigate and evaluate the dynamic properties of three type wood fibre/PP composites, and also to com-pare them with the values obtained from sitka spruce wood and particleboard. The feasibility of using as the musical sound boards and speeker boxes for these composites was also discussed based on the property data obtained from solid wood and wooden panel of this test and the others.

The materials used are those discarded wood fibres – sander dusts (SrD), wood fines (W.F.), sawdust (SwD) – and polypropylene (PP) composites. With each contained five levels of fibre content (F.C. 10, 20, 30, 40 and 50%) and a set of pure polypropylene (PP or F. C. 0%) specimens were injection moulded. Similar size air dry sitka spruce wood (parallel to and perpendi-cular to wood grain) and larger size particleboard (19x 1.5 x 0.6 cm) specimens were also prepared.

All tests were carried out strictly in accordance with the standard method (bending vibration) developed in here institute. The results were then analysed and compared statistically.

1. E′ values of composites, spruce wood and particleboard tended to be higher than those obtained from their static flexural elastic modulus (F.E.M. or E) values. The difference between E′ and E values varied noticiablily by the percents F. C., types of composites, specific gravity and the materials.
2. F.E.M. or E values of three type composites correlated significantly with their E′, loss modulus E′, loss tangent (tan δ) and logarithmic decremnet (λ).
3. Static maximum flexural strength (M.F.S.) of three type composites on the other hand, correlated only with their E′.
4. Three type composites seemed to be feasible for applying as the sound board or box of musical instrument since their dynamic properties are quite close to those of solid wood, particleboard as well as hardboard which have satis-factorily been applied for it.
5. It will be encouraged to see that the using of wood fibre/plastic composite materials to fabricate the musical sound boxes of any size and shape by injection moulding or other processes.

Key words: Dynamic elastic modulus, loss modulus, loss tangent, logarithmic decrement, resonant-dumping curve, internal friction.

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[1] Faculty of Forestry, University of Toronto. Visiting specialist of Taiwan Forestry Research Institute.
[2] Department of Wood Utilization of Taiwan Forestry Research Institute.
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木材／塑膠複合材料之研究開發(Ⅱ)三種木纖維／PP複合材，雲杉木及粒片板之動粘彈性

彭武財[1)]　　黃彥三[2)]　　陳玉秀[2)]

摘　要

本研究之目的在探討三種木材纖維／聚丙烯複合物之動態特性，同時與雲杉材及粒片板之性質互作比較。此外，此等複合材料使用作音響材料之可行性亦加以討論，並與其他研究者所獲致之性質相比較。

所使用材料爲工業廢棄木材纖維—砂光粉、鉋屑末、鋸屑—與聚丙烯之複合物，各組具五種水準之纖維含量(10, 20, 30, 40及50%)及一組純聚丙烯，同時亦準備氣乾雲杉材及粒片板。

所有試驗經採用標準規格及由試驗室所發展之動態及靜曲試驗方法。結果經分析及作統計結論。玆將主要成果分列如下：

1. 三種木材纖維／聚丙烯複合物中具較高木材纖維含量者似乎頗適合作爲音響材料，因其動態性質與粒片板、硬質纖維板及其他木質材料頗相接近。
2. 木材纖維／聚丙烯複合材、實木及粒片板之靜曲彈性係數E均較動彈性係數E′爲低，E與E′之差因材料及木材纖維含有量之比率而有大差異。
3. 三種複合材料之靜曲彈性係數E與動彈性係數E′，損失彈性係數E″，損失正切tan δ 及對數衰減率 λ 間有顯著相關性存在。
4. 複合木材之靜曲強度與動彈性係數E′間具有相關性。
5. 木材纖維／聚丙烯複合物可利用射出成型技術製作不同形狀之音響箱材。

關鍵詞：動彈性係數、損失彈性係數、損失正切、對數衰減率、共振—衰減曲線、內部磨擦。

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Introduction

Wood fibre/plastic composites are newly developed, economically valucable materials which capable to be utilized for many industrial purpose applications. These composites can be considered as the musical instrument materials such as the sound board and speaker box etc. by means of high ratio of wood fibres evenly contained in them but still well possess a certain degree of plasticity. A good acoustic performance plus a marvelous fabricability (by injection moulding) for these materials therefore, could be expected.

Dynamic mechanical test usually gives a quick and a precise property informations of materials especially in regarding to those of highly sensitve structure problems. The stress and the strain of material after subjected by a sinusoidal or other periodic stress generally are not in phase, and therefore, these two quantities can be determined respectively based on the principles of dynamic theory as a modulus and a phase angle or a damping term.

The instruments used for this type test – dynamic mechnical test – are often varied, such as the free vibrations, resonance forced vibration, nonresonance forced vibrations, and the wave or pulse propagation test instruments etc. (Ferry, 1958; Eirich, 1970; Nielsen, 1962). Any one of these instruments can be used different types of apparatus to cover the desired frequency range, and the results obtained are given similarly in terms of complex moduli of a dynamic elastic modulus and a term of loss modulus or damping or energy dissipation as mentioned.

The role of mechanical damping often is the most sensitive indicator of all kinds of molecular motions (for plastic polymers) and interface movements (for wood/plastic composites) which are going on in a material, even in the solid stae. These motions therefore, are great importance in determining of the mechnical behaviour of polymers and their composites. For this reason, the absolute value of the damping and the temperature, frequency at which damping peaks occure are important parameters for all aspects.

There are many reports in regarding to the dynamical behaviours of plastic polymers and composites (Nielsen, 1974), plastic and wood fibre composites (Waitkus, *et al.*, 1993). The behaviours of wooden materials also can be noticed from wider ranges of reports (Bell, *et al.*, 1954; Kollmann, *et al.*, 1968; Hearmon, 1966; Wu, *et al.*, 1974; Kitahara, *et al.*, 1973; Moslemi, 1967; Gerhard, 1978; Tonosaki, *et al.*, 1983, 1985; Huang, *et al.*, 1989; Sobue, 1982; Moore, *et al.*, 1983.).

This test was purposed to determine the true dynamic properties of composites and also to clarify the effect of wood fibre on their properties. The properties of solid wood, particleboard and other wooden panels of simultaneously tested and refered from other reports were used for comparing and evaluating of the applicability of three composites as sound board or box of musical instruments. The properties of statically tested (Peng, *et al.*, 1994) were also used for comparing those of dynamically tested.

Materials and Experiments

Three types of industry rejected wood fibres – sander dusts (SrD), wood fines (W.F.) and sawdust (SwD) – were used as polypropylene (PP) reinforcing materials to produce three type composites. Five levels (10, 20, 30, 40 and 50%) of fibre contents (F.C.) were set to each type composite, and a set of pure PP (or F.C. 0%) was for standard. Six (6) specimens (14 x 1.3 x 0.3 cm) each every F.C. were selecte from every type composite; twenty (20) pieces each of air dry sitka spruce of similar size, with wood grain parallel to and perpendicular to span direction were cut carefully from four pieces of 2x6 cut-offs; eighteen (18) pieces of 20 x 1.7 x 0.6 cm size (instrument maximum allowed) particleboard specimens were cut from home made three (3) panels of uniformally layered, 0.70–0.89 sp. gr. and 10 % UF content.

Each specimen was measured carifully the thickness, width and specific gravity priorly, and the test was carried out the dynamic first, and then, the static flexural for all of them.

The detailed setup for this test is illustrated as Fig. 1. A small piece of conductive silver priorly stuck on the end face of each specimen, and the other end was fastened on the vibration driver leaving a specified length of span. The reed was mounted virtically to the end face of specimen, and the pick-up tip was adjusted to be directly face to its silver, but kept a distance which can recieve a most desired sensitiveness from the recorder as Fig. 2 shows.

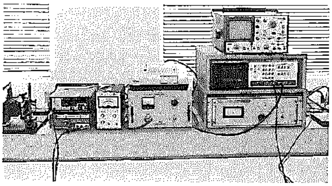

Fig. 1. A vibrating reed apparatus for measuring the dynamic viscoelasticity.

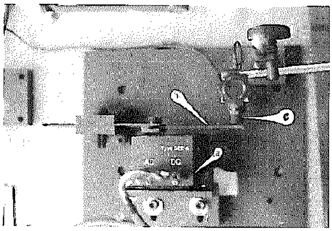

Fig. 2. Top view of the vibrator driver (a), fastened specimen (b) and the pick-up head (c).

The natural frequency, dynamic elasticity, loss modulus, loss tangent and logarithmic decrement were determined based on the respective data obtained from X-Y recorder. Static flexural elastic moulus and its maximum strengths of three composites, spruce wood and particleboard were determied strictly in accordance with ASTM methods for plastics.

Basic Teory

Dynamic property results are generally given in terms of complex moduli or compliances E^* (Perry, 1970; Nielsen, 1962, 1974; Moslemi, 1967; Huang, 1986), which are defined by;

$$E^* = E' + iE''$$

Where E' is the real part of the modulus, and also called the dynamic elastic modulus. E'' is the imaginary part of the modulus which is called the loss modulus. The index i in here is $= \sqrt{-1}$.

The loss modulus is a damping or energy dissipation term. The angle which reflects the time lag between the applied stress and strain is δ, and it is defined by a ratio called the dissipation factor:

$$\tan \delta = E''/E'$$

Where $\tan \delta$ is a damping term and is a measure of the ratio of energy dissipated as heat to the maximum energy stored in the material during one cycle of oscillation, and it is also called loss tangent which can be expressed as the internal friction of Q^{-1} as follows;

$$\tan \delta = Q^{-1} = E''/E'$$

For the small to medium damping, the dynamic elastic modulus E' is close similar to the shear modlus measured by other methods at comparable time scales.

When it is in the case of rectangular cross sectioned specimen, it usually can be determined from the following equations (Den Martog, 1956; Tomoshenko, *et al.*, 1969; Huang, 1986; Tonosake, *et al.*, 1983) based on the method of free-free vibration of rod supported at nodal points:

$$E' = \frac{48\pi^2 \ell^4 \rho}{a_o^4 h^2} (f_r^2 + (\triangle f)^2/8)$$

Where ℓ is the span length, cm. ρ is the density of specimen, g/cm^3. fr is the resonance frequency, Hz. h is the specimen's thickness, cm. $\triangle f$ is the difference of f_2 and f_1 of two $1/\sqrt{2}$amplitude frequencies. The value determined from $(\triangle f)^2/8$ practically is quite small comparing with that of f_r^2, and it usually can be ignored.

a_0 is a constant depending on the mode of the vibration. For the fundamental vibration $a_0 = 1.875$.

The resulted moduli are given in dynes/ cm^2, and the relation between kgf/cm^2 and $dyne/cm^2$ can be determined by;

$$1\ kgf/cm^2 = 980{,}000\ dyne/cm^2.$$

The quantity $(f_2 - f_1)/f_r$ is equal to E''/E', and the E'' also can be determined from the following equation;

$$E' = \frac{48\pi^2 \ell^4 \rho}{a_0^4 h^2} (f_r \triangle f)$$

The internal friction Q^{-1} also can be determined from be following equation approximately;

$$Q^{-1} = \tan \delta = E''/E' \fallingdotseq \triangle f/f_r$$

The logarithmic decrement λ can be determined based on the principle of loss tangent and logarithmic decrement relation;

$$\lambda \fallingdotseq \pi \tan \delta$$

Results and Discussion

1. Dynamic Properties of Three Composites

The effect of fibre content (F.C.) on the dynamic properties of three composites are illustrated on Fig. 3, 4, 5, 6, and 7.

(1) Resonant-Dumping Curves

The resonant-dumping curves for PP (F.C. 0%) and F.C. 30%, 50% of three composites are shown as Fig. 3. The peaks appeared on the graduation of frequency linear (Hz) showed greatest on the WF composite, either F.C. 50% or its 30%. Following by the SwD and the SrD compostics. The peak of PP showed least.

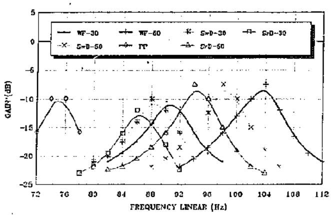

Fig. 3. Resnant-dumping courves for PP and three composites of fibre content (F.C.) 30% and 50%.

(2) Dynamic Elastic Modulus (E′)

The values of E′ increased near linearly by the increasing of F.C. for the WF composite, a slightly moderated on the SwD and largely deviated on the SrD composites as Fig. 4 illustrated. It varied noticeablily when the F.C. is higher than 40%. The highest is the composite of WF, and the lowest is on the SrD similarly to the case of static flexural elastic modulus E (Peng, W.T., *et al.*, 1994). The type and form of wood fibres therefore, are key factors influencing the stiffness of finished composites. The using of wood flour-like sander dust (SrD) as the reinforcing material for plastics consequently, has to be reconsidered.

The lowest E′ in the PP is 23.66×10^3 kgf/cm^2 (2.32×10^{10} $dynes/cm^2$), and the highest in the WF composite of F.C. 50% is 50.61×10^3 kgf/cm^2 (4.96×10^{10} $dynes/cm^2$). It reveals that the adding of WF to plastic to 50% could doubling the E′ value.

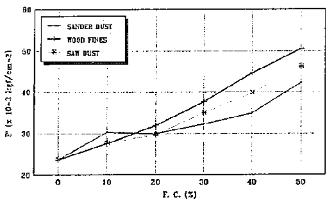

Fig. 4. Effect of fibre content (F.C.) on the dynamic elasticity (E″) of three composites.

(3) Loss Modulus (E″)

The overal effect of F.C. on the E″ value on the other hand, is quite modest. A close linearly increasing from F.C. 0% (or PP) to 40% is demonstrated on the WF composite, no change from F.C. 10% to 40% is on the SrD, and a moderately increasing from F.C. 20% to

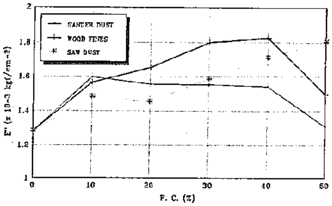

Fig. 5. Effect of fibre content (F.C.) on the loss modulus (E″) of three composites.

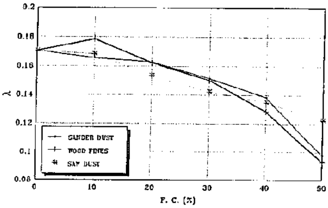

Fig. 7. Effect of fibre content (F.C.) on logarithmic decrement (λ) of three composites.

50% is on the SwD composites. The E″ value dropped drastically at the F.C. 50%. of both WF and SrD composites. Oveall highest E″ is found on the composites of WF, and the lowest is on the SrD composite as Fig. 5 illustrated.

(4) Loss Tangent (tan δ)

The influence of F.C. on tan δ or internal friction (Q^{-1}) however, is a quite negative (Fig. 6), and it especially showed severe on the F.C. 50% of all composites. Statistically shows no differences among three compósities. The highest value is read from the WF composite of 10% F.C. and the lowest is also on same composite of F.C. 50%.

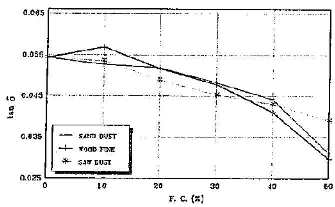

Fig. 6. Effect of fibre content (F.C.) on the loss tangent (Tan σ) of three composites.

(5) Logarithmic Decrement (λ)

The effect of F.C. on λ value is illustrated as Fig. 7. An almost identical pattern of distribution as that of the case of tan δ, in which, all tend to be negatively influenced by F.C..

2. Comparison With Other Results

Table 1 lists a comparison of E′, E″, tan δ and λ values obtained from this test and the data from other references. The used units were all unified to be dyne/cm².

It shows clearly that the E′ values of three composites are quite clossly fallen into the applicable limits of sound boards evaluated from particleboards (Huang, *et al.*, 1989), 30 °and 15 °grain directed sitka spruce wood (Tonosaki, *et al.*, 1983), red meranti and sitka spruce plywood (Sobue, 1982) and hardboard (Moslemi, 1967).

A comparatively greater E″ values are found from three composites as those of the others, with the exceptions of particleboard (Huang, *et al.*, 1989), beech (Huang, 1986) and epoxy-poplar composite (Moor, *et al.*, 1983) which show satisfactorily close. The stress damping or the energy dissipation of three composites consequently, is severer than those obtained from the other materials. The type of material and the from of compostion seemed playing impotant roles on it.

The tan δ value of three composites is also showed a slightly higher than those obtained from the other solid wood and wood composites. Particleboards obtained from two tests (Huang, *et al.*, 1989, Peng, *et al.*, 1995) can fell satisfactorily into this level. It might strongly related to the viscoelasticity of materials tested.

Table 1. Dynamic Properties of Wood Fibre/PP Composites, Solid Wood and Wood Composite Materials

Property / data from	E′ (x10[10] dyne/cm[2])	E″ (x10[8] dyne/cm[2])	tan δ (x10[-3])	λ
P-PP	2.32	12.58	54.27	0.170
P-SrD/PP	2.97- 4.14	12.85-15.66	37.83-43.27	0.118-0.136
P-WF/PP	2.70- 4.96	14.67-17.89	29.59-56.87	0.093-0.179
P-SwD/PP	2.71- 4.53	14.25-17.70	39.07-52.58	0.123-0.165
P-SPWD	11.76-15.68	7.25-13.52*	11.23-17.51	0.035-0.055
P-PB	1.37- 2.46*	5.68- 9.99	35.34-46.31*	0.111-0.179*
1-PB	1.36- 2.84*	8.52-22.95*	19.22-30.70*	0.096-0.603*
2-SPWD	0.85- 5.86*	1.71- 6.91	6.50-22.00	0.020-0.063
3-PLWD	1.00- 3.30*	2.08- 4.35	11.80-22.00	0.037-0.069
4-SPBWD	1.05- 1.54	--------	--------	--------
5-HB	2.40- 5.50*	--------	--------	--------
6-BCWD	7.60- 9.96	8.37-11.80*	10.80-14.10	0.034-0.044
7-RCWD	9.09- 9.95	5.20- 5.63	5.66- 5.97	0.018-0.021
8-SPWD	13.79-14.87	9.40- 9.60	6.31- 6.82	0.020-0.021
9-EPPC	10.60-12.30	11.70-14.40*	10.70-13.20	0.034-0.042
10-PHPF	6.90- 7.25	--------	--------	--------

Notes: *P-PP*: Data from this test. Polypropylene. *P-SrD/pp, P-WF/PP, P-SwD/PP*: Data from this test. Sander dust, wood shaving fines, saw dust and polypropylene composites. *P-SPWD*: Data from this test. Sitka spruce wood. *P-PB*: Data from this test. Particleboard. *1-PB*: Data from Huang, Y. S. and *et al*, 1989. Particleboards. *2-SPWD*: Data from Tonosaki, M., Okano, T. and Asano, I., 1983. Sitka spruce wood. *3-PLWD*: Data from Sobuc, N., 1982. Red meranti and sitka spruce plywood. *4-SPBWD*: Data from Yano, H. and Yamada, T., 1984. Glehn's spruce plywoods. *5-HB*: Data from Maslemi, A. A., 1967. Hardboard. *6-BCWD, 7-RCWD, 8-SPWD*: Data from Huang, Y. S., 1986. Beech, red ceder, sitka spruce wood. *9-EPPC*: Data from Moore, G. R. and *et al*, 1983. Epoxy-poplar composite. *10-PHPF*: Data from Wailkus, P. A. and Olmsted, T. W., 1993. Phenolic pine wood flour composite, at 25℃ condition.

*: The property which is close to that of the wood fibre/PP composites.

3. Difference Between E and E′ values

Static and dynamic flexural elastic modulus (E and E′) of three composites, sitka spruce wood and particleboard of this test are illustrated as Fig. 8, 9 and 10 respectively.

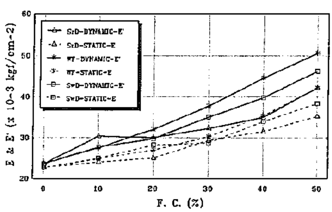

Fig. 8. Comparison of static and dynamic flexural elastic modulus (E and E′) of three composites.

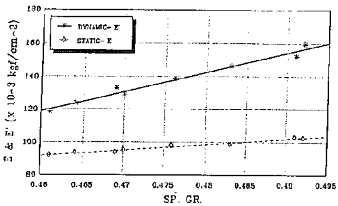

Fig. 9. Static and dynamic flexural elastic modulus (E and E′) of air dried spruce wood of grain direction parallel to span long dimention in relation to specific gravity.

(1) Three Type Wood Fibre/PP Composites

Overall mean preperties of dynamically and statically tested are summerized in Table 2. The influence of F.C. on E and E′ values of three composites is illustrated as Fig. 8.

Table 2. Statistics of Dynamic and Static Flexural Properties of the Composites of Wood Fibres of SrD, WF, SwD and Polypropylene

Composites		SrD × PP		WF × PP		SwD × PP		All	
Variables (Unit)	N	M	SD	M	SD	M	SD	M	SD
Den.	36	0.987	0.051	0.997	0.064	0.987	0.056		
(g/cm^3)	96							0.990	0.052
E′	36	33,089	6,098	35,906	9,587	33,668	7,794		
(kgf/cm^2)	96							34,221	7,456
E″	36	1,559	359	1,701	278	1,555	193		
(kgf/cm^2)	96							1,596	494
tan δ	36	0.0480	0.0106	0.0491	0.0081	0.0474	0.0060		
	96							0.0461	0.0140
λ	36	0.1507	0.0334	0.1543	0.0253	0.1490	0.0189		
	96							0.1513	0.0440
M. F. S.	36	504	14	534	24	535	22		
(kgf/cm^2)	96							526	26
F. E. M.	36	18,619	3,211	20,351	4,536	19,816	3,592		
(kgf/cm^2)	96							20,141	3,742

Notes: *N*: Numbers of specimens tested. *M*: Mean value. *SD*: Standard deviation. *Den*: Density or specific gravity. *E′*: Dynamic flexural elastic modulus. *E″*: Loss modulus. *tan δ*: Loss tangent. *λ*: Logarithmic decrement. *M. F. S.*: Static maximum flexural strength. *F. E. M.*: Static flexural elastic modulus. It is also expressed as *E* in this report.

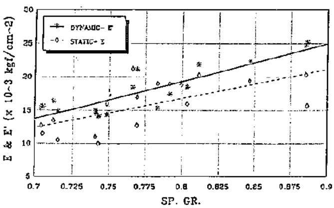

Fig. 10. Static and dynamic flexural elastic modulus (E and E′) of particleboard in relation to specific gravity.

Overall their E′ values show higher than their E values, and their differences varied greatly by the increasing of F.C. as indicated.

Table 3 tabulates their statistically calculated correlation coefficients and the degrees of significant (Pearson Correlation Coefficients/Prob. > R under Ho; Rho = 0 Condition) among and between the properties of dynamic and static tested.

E or F.E.M. is significantly correlated with E′, E″, tan δ and λ valuse. The static flexural strength (M.F.S.) on the other hand, correlated only with the E′, no correlation with E″, tan δ and λ.

(2) Spruce Wood and Particleboard

Fig. 9 and 10 illustrate the comparison of E and E′ values based on the specific gravity (sp. gr.) for spruce wood and particleboard. E′ values obtained from two materials show similarly larger than their E or F.E.M. values through the range of sp. gr. illustrated. Their differeces are around 29% in 0.48 sp. gr. for spruce wood, about 15% in 0.80 sp. gr. for particleboard and approximately 18% for

Table 3. The Tests of Pearson Correlation Coefficients / Prob > R Under Ho: Rho = 0 Condition for the Mean Dynamic and Mean Static Flexural Properties of All Three Type Wood Fibre / PP Composites

N = 96

Variables	Den	E′	E″	tan δ	λ	M. F. S.	F. E. M.
Den	1.0000	0.9604	0.2067	−0.4525	−0.4525	0.4462	0.9401
	0.0000	0.0001	0.0444	0.0001	0.0001	0.0001	0.0001
E′		1.0000	0.2568	−0.4168	−0.4169	0.5535	0.9507
		0.0000	0.0115	0.0001	0.0001	0.0001	0.0001
E″			1.0000	0.7665	0.7664	0.1511	0.2102
			0.0000	0.0001	0.0001	0.1417	0.0398
tan δ				1.0000	1.0000	−0.1917	−0.4255
				0.0000	0.0001	0.0613	0.0001
λ					1.0000	−0.1914	−0.4255
					0.0000	0.0617	0.0001
M. F. S.						1.0000	0.6380
						0.0000	0.0001
F. E. M.							1.0000
							0.0000

Notes: *Den*: Density or specific gravity. *E′*: Dynamic flexural elastic modulus. *E″*: Loss modulus. *tan δ*: Loss tangent. *λ*: Logarithmic decrement. *M. F. S.*: Static maximum flexural strength. *F. E. M.*: Static flexural elastic modulus. It is also expressed as *E* in this report.

the WF composite in its F.C. 50% conditions (Fig. 8).

4. Comparison of Dynamic Properties

The dynamic properties of spruce wood of two directions, particleboard and three type composites are illustrated on Fig. 11, 12, 13 and 14, based on their respective specific gravity.

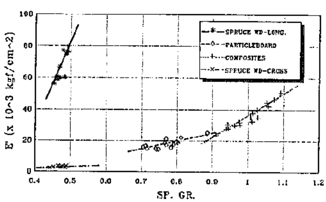

Fig. 11. Dynamic flexural elasticity (E′) of spruce wood, particleboard and wood fibre/pp composite vis Sp. Gr.

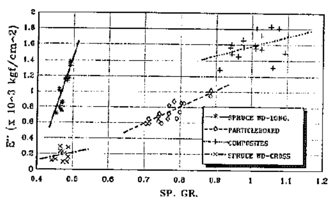

Fig. 12. Loss modulus (E″) of spruce wood, particleboard and wood fibre/pp composite vis specific gravity (Sp. Gr.)

The average E′ value of three type composites shows a slightly greater than that of the particleboard, but well in between the values of spruce wood two direction. E″ value of the said composites however, shows

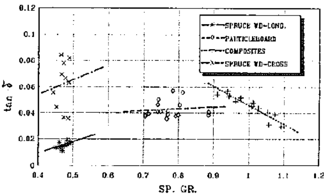

Fig. 13. Loss tangent (tan σ) of spruce wood of two direction, particleboard and three composites in relation with specific gravity (Sp. Gr.).

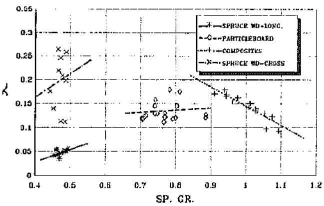

Fig. 14. Logarithmic decrement (λ) of spurce wood of two direction, particleboard and three composites in relation with specific gravity (Sp. Gr.)

somewhat higher than that of the others. Tan δ and λ values on the other hand, show almost the same levels for all materials.

It is an evidence that the three type wood fibre/PP composites can satisfactorily be applied as the musical instrument material which has already been dominated by the solid wood and other wooden materials.

Conclusions

Followings are the key findings from above results.

1. The increasing of fibre content (F.C.) increased the dynamic flexural elastic modulus (E′), loss modulus (E″), but decreased the loss tangent (tan δ) and the logarithmic decrement (λ) for three type wood fibre/PP composites.
2. E′ values in three composites, spruce wood and particleboard were found to be respectively higher than those (F.E.M. or E) obtained from their static flexural elastic modulus. The difference between E′ and E values varied by the percents F.C., type of composites, specific gravity and the materials.
3. F.E.M. or E values of three composites correlated significantly with the values of their E′, loss modulus E″, loss tangent (tan δ) and logarithmic decrement (λ).
4. Static maximum flexural strength (M.F.S.) of three composites on the other hand, only correlated significantly with their E′ values.
5. All three composites seemed to be quite suitable for applying as the sound boards or boxes of musical instruments since their dynamic properties were close to those of solid wood, particleboard and other wooden materials which have already been satisfatorily applied in this field.
6. It will be quite encouraged to see that the fabrication of musical sound boxes of any size and shape by an injection moulding process from three wood fibre/PP composites.

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