ICAS-98-4,4,4

A98-31590

SOME INVESTIGATIONS ON WOOD-COMPOSITE STRUCTURES FOR VERY LIGHT AIRCRAFT (VLA)

B. Jancelewicz, M. Rodzewicz, P. Czarnocki, L. Sałbut
Warsaw University of Technology
00-665 Warsaw, Poland

Abstract

The results are presented of some investigations on selected properties of elements representing the wood-composite structures useful for airframes of very light and ultra light aircraft. Wooden parts of the elements have been manufactured of the Polish pine and composite was glass-epoxy. Investigations on Young's modulus were performed with the use of four points bending beams for static values to be measured. Dynamic values of the modulus were measured using the one edge fixed beams free vibration frequency analysis. From this analysis the damping coefficient of free vibration amplitudes have been calculated. Dynamic values of Young's modulus of wood and composite as well have been found as 10 - 15% lower than the static ones. Damping coefficients versus frequency of free vibration of wood and wood-composite beams were found as non-linear. Investigation was also carried out on decreasing of strain concentration in wood - composite thin plate with knot in wood part. The fields of displacements and strains in elements tested have been found with the use of optical interference technique. Effective possibility of strains equalising was stated when using the one ply composite facing.

Introduction

Within the airframes of very light (VLA) and ultra light (ULM) aircraft the wood - composite elements may find the use. Interesting characteristics of these materials are the profitable relations of stiffness and - in many cases - also of strength to the weight of structure. One can state relatively easy and cheap manufacture and repair as well. Properties of wood and composite are known, however, when considering the wood - composite element, the new possibilities occur as not simple joint of the separate characteristics.

In wood - composite structures, similarly like in metallic ones two basic groups of elements assumed for load transmission can be selected. First - elements of compact cross - sections, say rods, parts of spar beams etc and second thin walled elements like plates, sheets and shells. Participation of particular elements in load transmission depends of relative fraction of their the stiffness defined statically and dynamically as well. The aim of investigation carried out was to test the influence of single basic composite layer on static and dynamic stiffness of rod form elements under bending load. From the test results there was possible to calculate Young's modulus values of single layer composite in wood - composite structure. The values can be different comparing with the ones measured for the same composite but of multiply structure. When selecting for dynamic tests the free bending vibration model, one can receive the possibility of measurements the damping coefficient of element.

Till now, the usefulness of wood for aeronautical structures has been concerned with the requirement not accepting any knots within the wood material for elements of important stiffness and strength role in structure. Such the selection of wood leads to increasing of material costs because, for example, sometime not more then 7 - 8% of total trunk of pine meets the aeronautical requirements. The use of composite facings on the wood element surfaces may decrease the influence of the knot on local strain concentration. Role of composite may depends on more intensive participation in load transmission, locally in surroundings of the knot. The investigations have been aimed to test the influence of single layer composite on strain concentration induced by small knot and on effective reduction of the strain concentration between first and next layers of composite.

Modulus of elasticity

An aim of the investigation performed was to calculate the Young's modulus of thin layer of composite glued "on wet" to the wooden rod.

The glass-epoxy composite has been selected of one layer Interglas 92125 reinforcing fabrics and mass fracture $m_f = 0.5$. For the rod the Polish pine was used including both, vertical grain and flat grain orientations. The fibres of composite reinforcement have been oriented parallelly and perpendicularly to the longest edges of wooden element. Data of the specimens are presented on Fig 1.

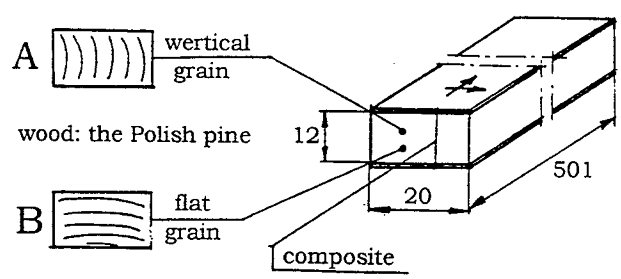

FIGURE 1 – Specimens for Young's modulus and damping coefficient investigation

21st ICAS Congress
13-18 September 1998
Melbourne, Australia

For Young's modulus calculation the four points bending model has been decided (Fig 2a). Curvature of the rod/beam tested under constant bending moment between supports has been calculated basing on the results of deflection measurement by the use of three (1, 2, 3 - Fig 2a) indicators. First the measurements and calculation were performed for wooden elements without composite facings. Bending stiffness of the elements was calculated. Next similar measurements and calculations were made for wood - composite specimens, where the wooden elements were the same.

From bending stiffness difference the stiffness of composite layer was possible to be found.

From this results the composite Young's modules under statically induced strains have been calculated.

For Young's modulus calculation under dynamically changed strains the free vibration model of one end fixed rod/bean has been selected (Fig 2b). At free end of the rod five different masses (0,5 - 2,5 kg) were fixed. Similarly as during the static measurements, first step was concerned with the wooden element without composite facings. The measurements were performed with the use of the same specimens as for static test. From free vibration frequency dynamic bending stiffness was calculated. The same procedure was used for wood-composite bending stiffness calculation.

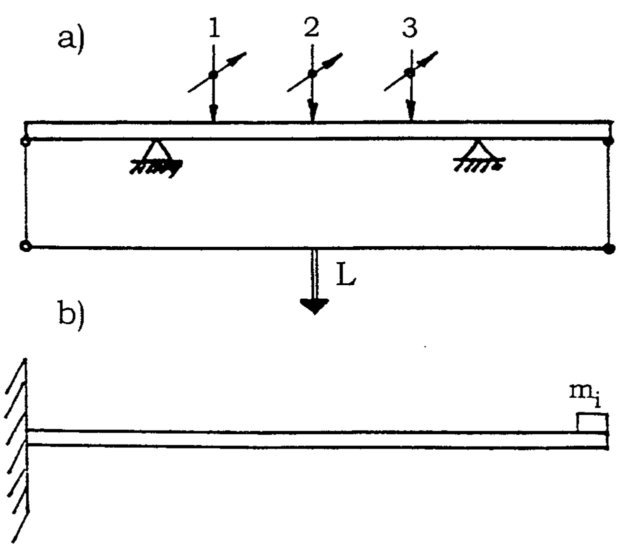

FIGURE 2 – Schemes of the models for static (a) and dynamic (b) investigations

Influence of the masses and wood grain orientation on free vibration frequencies for wooden and wood - composite rod/beans is presented on Fig 4a,b.

Results of Young's modules measurement and calculation are placed in Table 1 (Fig 3). E_s - is the Young's modulus value resulting from static measurements and E_d - from dynamic ones. One can see the results from dynamic measurements as of 15 - 20% lower for wooden elements and only of ~ 4% for composite facing. The last is comparable with the accuracy of measurements.

Table 1. E [MPa]

	WOOD			COMPOSITE		
grains	E_s	E_d	E_d/E_s	E_s	E_d	E_d/E_s
	13290	11380	0.856	9710	9300	0.958
	14830	11950	0.806	9850	9490	0.963

FIGURE 3 – Results of Young's modulus investigations.

When analysing the results, one can underline possible influence of shear strains existing in dynamic model on the deflections measured. Second important statement is that the Young's modulus values of single layer composite are of around 35% smaller than of multiply composite of the same reinforcement, matrix and fabrics mass fraction. Probably the edge effect is to be considered as of important influence.

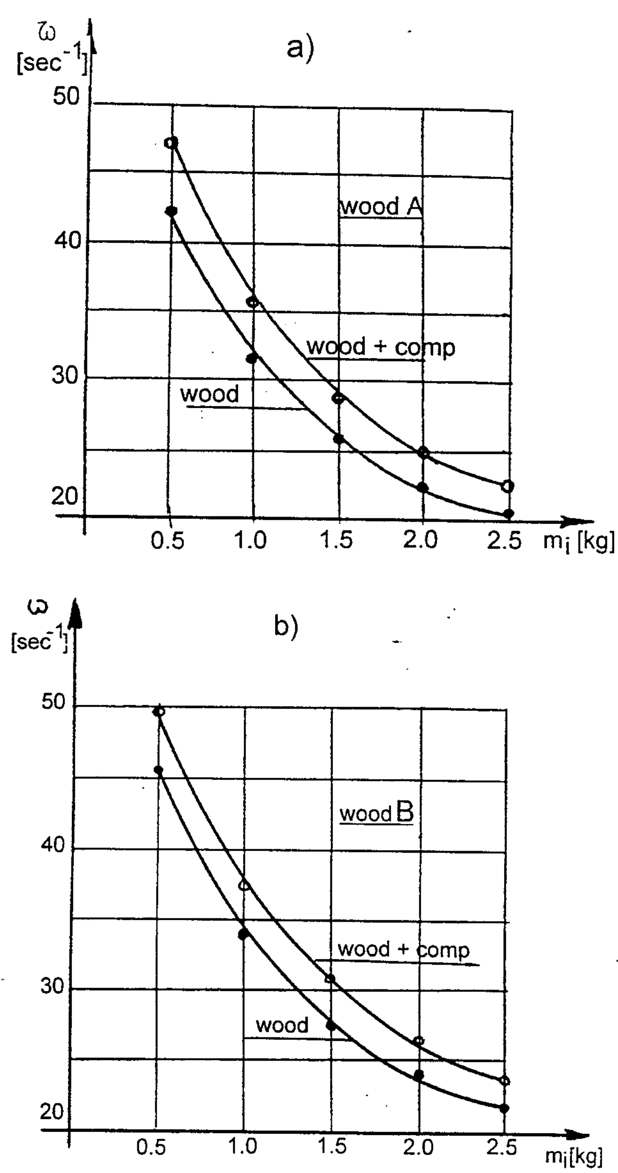

FIGURE 4 – Free vibration frequency versus mass m_i of Fig 2b model specimen a) with wood A, b) with wood B.

Vibration damping coefficient

Basing on the results of free vibration recording there was carried out the analysis of damping coefficient as a function of mass fixed at the free end of rod/beam (Fig 5a, b) as well as a function of vibration frequency. Calculations of damping coefficient were performed selecting the area of amplitude changes for each mass from the same maximum value up to the amplitude two times lower than maximum. The numbers of cycles were, of course, different. From the results presented on Fig 5 and Fig 6 this is visible important influence of composite facing on increasing of damping coefficient.

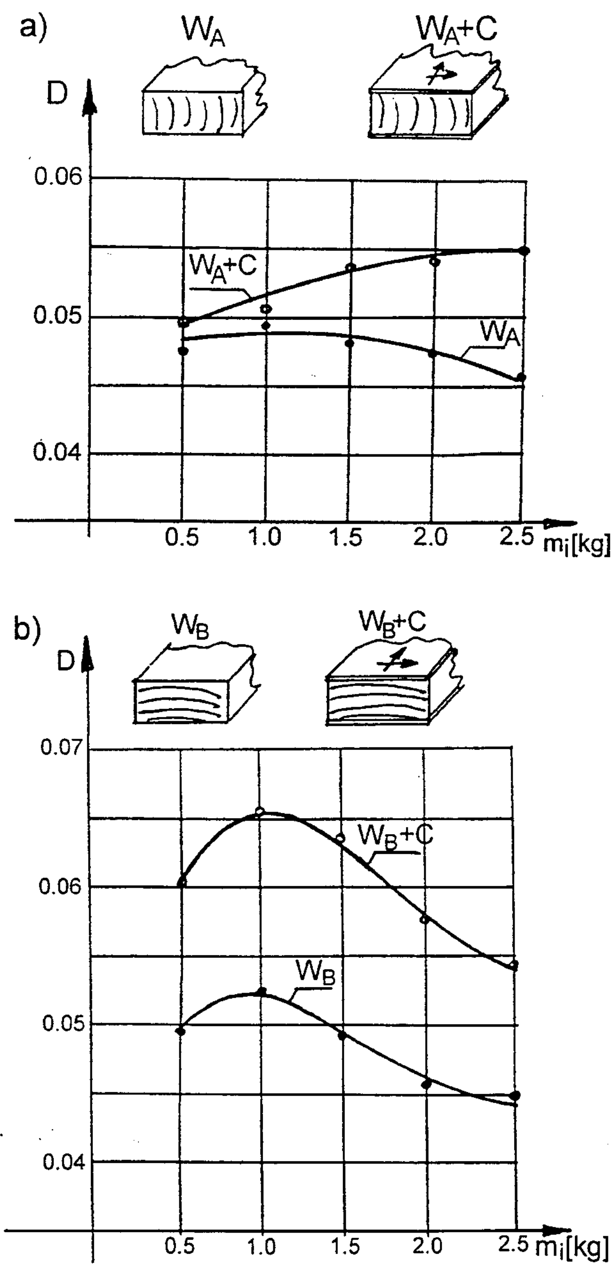

FIGURE 5 - Free vibration damping coefficient of wood and wood composite specimens of Fig 2b model:
a) wood A and wood A + composite specimens;
b) wood B and wood B + composite specimens.

However more important observation is that the change of the damping coefficient versus mass m_i or versus frequency is non-linear both for wooden (W_A = wood A, W_B = wood B) and for wood-composite bar/beams (W_{A+C} = wood A + composite facings, W_{B+C} = wood B + composite facings).

From these observations may result also the conclusion that damping coefficient is also non-linear function of the amplitudes.

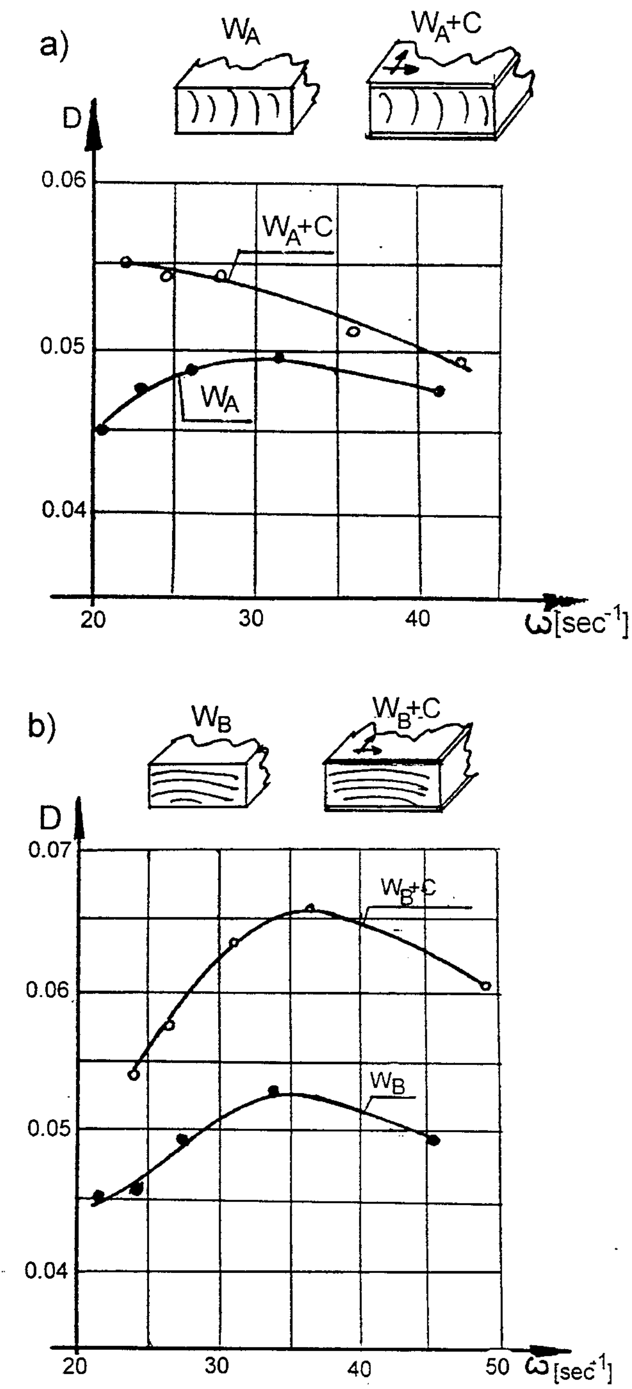

FIGURE 6 – Free vibrations damping coefficient versus frequency of the vibrations for the same change of vibrations amplitudes. Specimens: a) with wood A, b) with wood B.

Strain concentration within knot zone

Knot within the wood can be considered as a natural discontinuity inducing, when loading, local strain concentration in grains surrounding the knot. An aim of the investigation presented was to check the possibility of strain concentration mitigating with the use of thin-walled composite facings covering the knot and its surroundings as well. As an object of investigation the thin wooden plate with small central knot has been selected. Grains of the knot were of perpendicular direction to the surfaces of the plate.

On Fig 7 the specimen tested is presented. The wooden element has been made of the Polish pine, which met the aeronautical requirements. The facings were of single layer glass - epoxy composite the same as used in rod/bean structures investigations described. For displacements and strain measurements an optical interference method was used. The orthogonal interference grating of 1200 lines/mm. Was selected to be fixed first on wood with knot and next on the surface of composite facing glued on the wood element. External load applied was the tension parallel to y-axis of specimen.

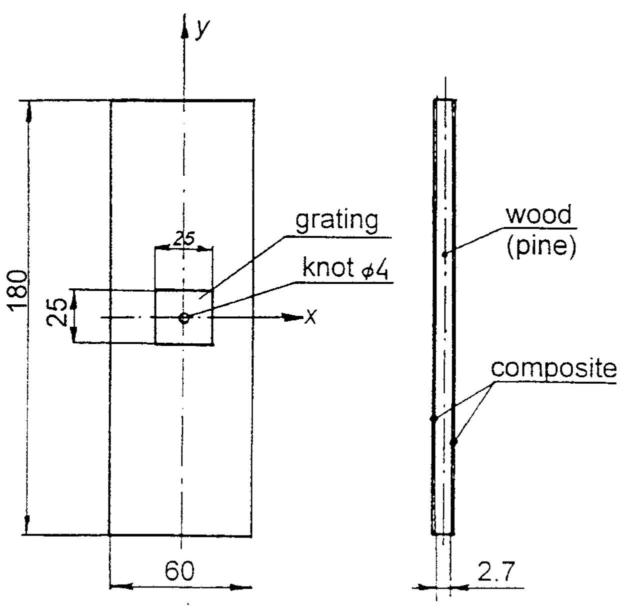

FIGURE 7 – Specimens for strain distribution investigations.

Interferometric fringe patterns in wood with knot resulting from the strains of wood element are presented on Fig 8 a, b. The zone of knot is visible very precisely. After covering the element with composite facings (fibres of fabrics parallel to y-axis and x-axis) the interferometric fringe patterns resulting from strains of the facings zone covering the knot indicates importantly lower strain concentration. The zone of knot is very difficult to be detected (Fig 9a, b). This result is fully confirmed when analysing the ε_y strain distribution for instance along y-axis of the specimen (Fig 10a, b).

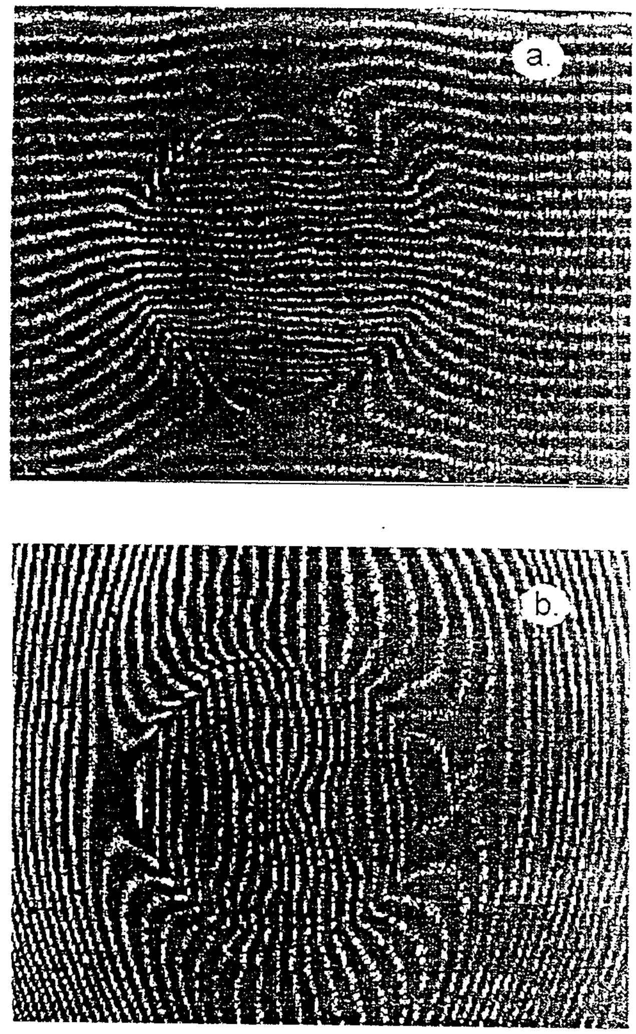

FIGURE 8 – Interferometric fringes resulting from strain of wood plate with knot of 4 mm in diameter
a) y-direction displacements field, b) x-direction displacements field

General conclusions

The investigations carried out have indicated the usefulness of composite facing for wood elements, even when the facing is of one composite layer only.

The stiffness of rod/beam and damping properties of the structure can be importantly improved. In case of thin - walled elements with local discontinuity the strain concentration induced by that can be effectively mitigated (Fig 9, Fig 10).

One can take into account that some increasing of mass because of higher composite density comparing with the one of wood looks to be acceptable.

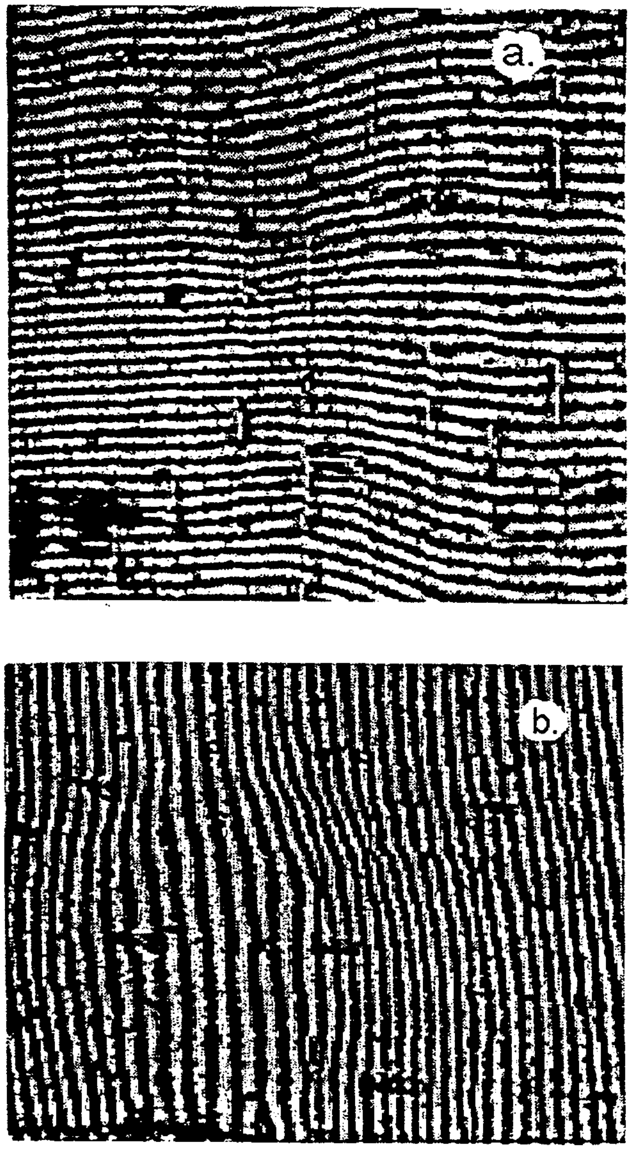

FIGURE 9 - Interferometric fringes resulting from strain of composite facing covering the knot; a) y-direction displacements field, b) x-direction displacements field.

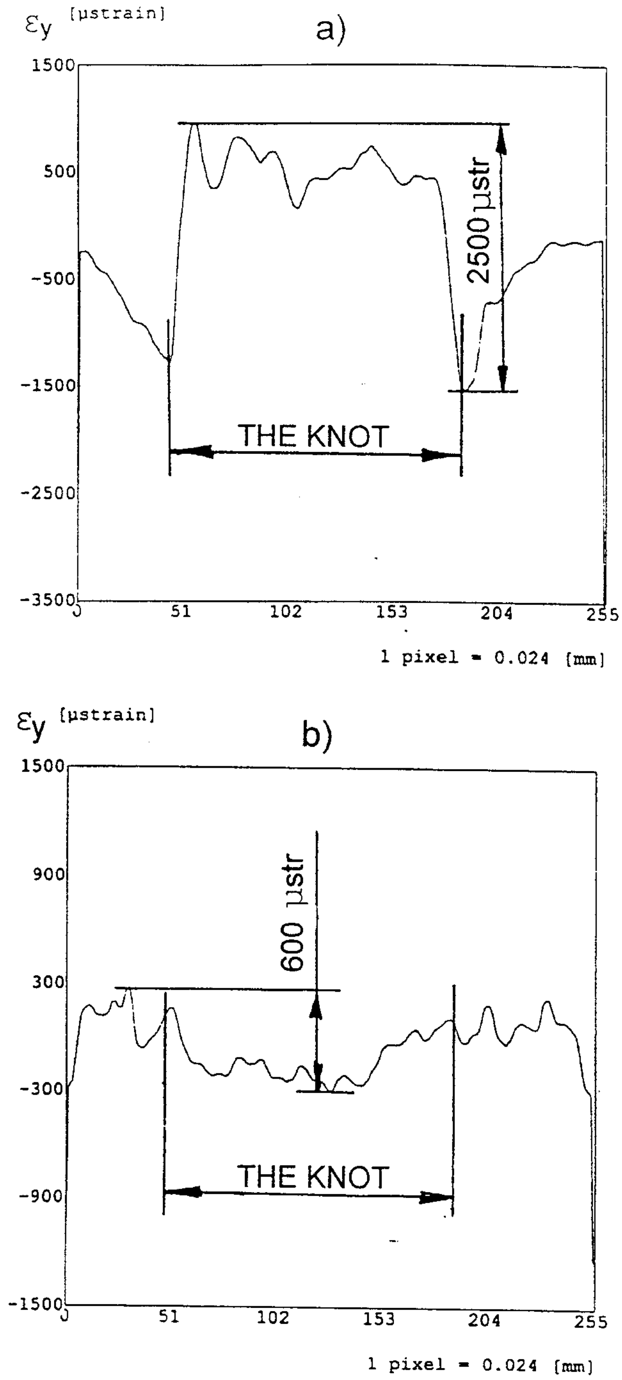

FIGURE 10 - ε_y distribution along y axis a) in wood with knot, b) in composite facing fixed at the same place.

Acknowledgement

The investigations carried out as a part common programme in Warsaw University of Technology and Karlstad University (Sweden) were financially supported by Rector of Warsaw University of Technology in form of special grant.