# Effect of the Mean Diameter Increment on the Pine Wood Mechanical-Physical Properties in Lithuania

**MARIUS ALEINIKOVAS**
*Lithuanian Forest Research Institute, Liepu st. 1, Girionys, LT-53101, Kaunas distr., Lithuania,*
*Phone +370 37 547283, Fax +370 37 547446*

**Aleinikovas, M.** 2007. Effect of the Mean Diameter Increment on the Pine Wood Mechanical-Physical Properties in Lithuania. *Baltic Forestry*, 13(1): 103–108.

*Abstract*

The paper presents the evaluation and comparison of some physical and mechanical properties of Scots pine (*Pinus sylvestris* L.) wood in stands with different growth type. The data have been collected on the basis of 9 sample plots. There were aspired that pine stands chosen for wood analysis could have as much familiar structure and identity character of stand growth as possible. Though, the requirements retained for using the mean diameter increment (cm per year) in maximum index (*dv*) for classification of dominant trees growing. According to this index, the pine stands were divided into three *dv* groups: 0.3, 0.5 and 0.7 cm per year, when the age in maximum ($A_k$) was from 15 to 36 years.

Wood samples were taken at the stem butt-end. The average annual ring width, late wood percentage in annual ring, wood density, bending strength in tangential direction and compression strength along the grain were determined in the samples.

It was estimated, that wood density, bending strength and compression strength of pine trees from the analysed three *dv* groups have differed significantly. It is considered that pine wood has the most proper physical and mechanical properties when the stand stocking level is between 0.8 – 0.9.

**Key words:** Scots pine, the mean diameter increment in maximum index, wood physical - mechanical properties

## Introduction

The structure and properties of wood are affected by genetic, environmental and anthropogenic factors acting during formation of wood cells and tissue (Wodzicki 2001). The analysis of the influence of a chosen factor becomes inconvenient. However, these data are obtained while investigating the wood properties from the stands.

Sufficient light, warm and humidity conditions, the dioxide amount in the atmosphere, also the supply of nutrients and oxygen in the soil are necessary for beneficial tree growth. The biological properties of tree species, ecological habitat conditions and dominant fluctuation of climatic factors influence singularity of the dynamics of tree annual diameter increment (Bitvinskas 1997, Karpavičius 2005). Consequently, the annual ring width and the structure integrally reflect the influence of all ecological factors (Ozolinčius 1998). This indicates that structural and physical wood properties can have wide variation of respective indicators. Though, the tree annual diameter increment also is one of major indicators representing tree vitality (Juknys *et al*. 2004).

While investigating the dynamics of pine radial increment, it was found that annual ring width depends on the stand structure and specificity of stand development (Grigaliūnas 1997a). Therefore, the wood properties of the mature stands with similar diameter but depending on the different development type can differ. To eliminate these differences it was proper to evaluate the mean diameter increment (cm per year) in maximum $d_v$ and age in maximum ($A_k$). These indexes show the subsequent diameter growth and are relatively stable and reflecting the stand structure (mostly primary stand density), habitat quality. Though, it is easy to determine by measuring annual rings in bore samples (Grigaliūnas 1998). Also, the derivative index allows to classify the stands by similar structure in the range of the habitat and properly to estimate the wood properties.

Index dv and stands site index are closely related ($r^2 = 0,67$) (Fig. 1). Both indexes characterize site productivity but there is the significant difference: the mean diameter increment in maximum reflects the progress of stand development.

The aim of this study was to evaluate and compare some physical and mechanical properties of Scots pine *(Pinus sylvestris* L.) wood in stands with different mean diameter increment in maximum (*dv)* in Lithuania.

### Materials and methods

Studies were conducted on 9 pine stands from Nb (normal humidity poor site) forest site. The age of stands was from 80 to 100 years. The radial increments from 90 dominating trees were measured by microscope. The width of annual rings, percent of late wood, wood density, bending strength and compression parallel grain strength were estimated conducting the research. While determining wood properties the test standards (ISO 3130:1975, ISO 3131:1975, ISO 3133:1975, ISO 3132:1975) were followed.

In each selected stand the wood bore samples were drilled in ten chosen tree stems at the 1.3 m height for measuring the width of annual rings, the percentage of latewood and the mean diameter increment in maximum ($d_v$) index.

It was aspired that the pine stands chosen for wood analysis could have as much familiar structure and identity character of stand growth as possible. Though, the requirements retained for using $d_v$ for classification of dominant trees growing on the corresponding pine forest site. According to this index, the pine stands were divided into tree $d_v$ groups: 0.3 (0.201 – 0.400), 0.5 (0.401 – 0.600) and 0.7 (0.601 – 0.800) cm per year, when their age in maximum ($A_k$) was from 15 to 36 years.

The mean diameter increments were calculated for each tree as follows:

$$d_v = D_{zr}/(A_{1.3} + n) \quad (1)$$

where: $d_v$ - the mean diameter increment at age $A_{1.3}$, + n, cm per year; $D_{zr}$ - the diameter of a tree at age $A_{1.3}$ + $n$, cm; $A_{1.3}$ - the number of years until a tree grows up to 1.3 m high; $n$ - the number of the annual tree rings at the height of 1.3 m for each $d_v$, units (Grigaliūnas 1997).

For measuring the wood density and mechanical properties, two sample trees in each stand were randomly selected. The north and south directions were marked on the standing sample trees. Wood density, bending strength in tangential direction as well as compression strength along the grain of pine wood were studied based on small clear specimens. The study was conducted with 2 m long butt logs cut from the sample trees. From the central part of each log, a 75 mm thick board was cut, oriented along the north - south direction, including the pith. The boards were dried to air dry condition (MC ca. 12 %). Methods of preparing wood samples were presented by Aleinikovas and Grigaliūnas (2006).

The number of wood samples necessary for reliable determination of individual wood properties was ascertained applying statistical methods (Saladis and Aleinikovas 2004).

### Results and discussion

Figure 1 shows the dynamics of the mean diameter increment in maximum of the pine stands.

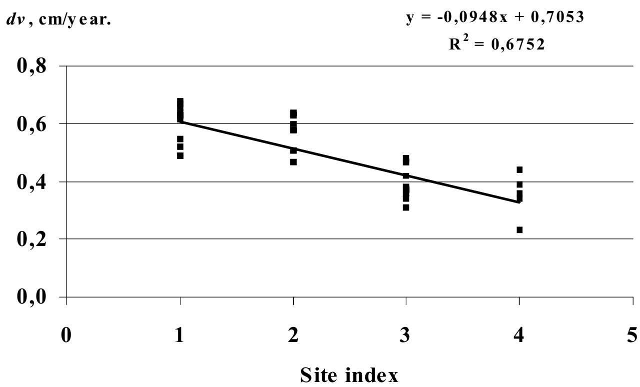


**Figure 1.** Dependence of the mean diameter increment in maximum (*dv)* on site index

Grigaliūnas (1997b) obtained the similar distribution of $d_v$ curves in researching the radial increment of Lithuanian pine stands. Intersecting increment curves covered a wide area, which was characterized by differing site quality, their combinations with stand structure and stand age. Such distribution *of* $d_v$ curves was related with inequality of soil properties on forest site. In some stands pine trees at the beginning grew more slowly and their radial increment increased gradually for a long time, therefore the trees diameter at breast height (DBH) was less in following stands. Other pine stands from the start grew more rapidly, however, their increment further remained at culmination level and in following stands the trees DBH was bigger.

According to the mean diameter increments in maximum index, the pine stands were divided into tree $d_v$ groups: 0.3, 0.5 and 0.7 cm per year, when their age in maximum ($A_k$) was from 15 to 36 years (Fig 1).

The data on physical and mechanical properties of pine wood from stands with different mean diameter increments in maximum index are shown in Table 1.

As the results show, the smallest annual ring width (1.51 mm) and the biggest latewood percent (36.18 %) was estimated in wood of trees from stands, with $d_v$ = 0.3 cm per year, while the biggest annual ring

**Table 1.** Average pine wood properties in the studied forest site types

| *dv*, cm/year | Stand No. | Width of annual rings, mm | Latewood, % | Density, kg m$^{-3}$ | Bending strength, MPa | Compression strength ‖, MPa |
|---|---|---|---|---|---|---|
| 0.3 | 1 | 1.75 | 33.26 | 631 | 95.19 | 79.76 |
| | 2 | 1.29 | 37.77 | 587 | 85.55 | 77.71 |
| | 3 | 1.48 | 37.51 | 558 | 79.12 | 71.49 |
| | Average | **1.51 ± 0.05** | **36.18 ± 0.68** | **591 ± 10.54** | **86.22 ± 2.12** | **76.19 ± 1.82** |
| 0.5 | 4 | 1.76 | 37.76 | 567 | 97.75 | 86.87 |
| | 5 | 1.86 | 35.42 | 586 | 97.10 | 84.54 |
| | 6 | 1.77 | 34.80 | 565 | 83.17 | 76.03 |
| | Average | **1.80 ± 0.04** | **35.99 ± 0.71** | **572 ± 7.64** | **92.67 ± 2.26** | **82.48 ± 2.13** |
| 0.7 | 7 | 1.77 | 37.69 | 548 | 77.09 | 70.72 |
| | 8 | 1.87 | 35.66 | 510 | 77.34 | 74.12 |
| | 9 | 2.42 | 34.32 | 515 | 78.22 | 69.16 |
| | Average | **2.02 ± 0.07** | **35.89 ± 0.66** | **525 ± 9.89** | **77.55 ± 1.58** | **71.25 ± 1.81** |

width (2.02 mm) and the smallest latewood percent (35.89 %) was estimated in the wood of trees in pine stands with $d_v$ = 0.7 cm per year. The essential differences between all $d_v$ groups of stand sites were found in determining annual rings width of tree wood, while latewood percent did not differed essentially between all $d_v$ groups.

The primary stand density influences the annual rings width, and it is one of the major stand indicators. It determines the currently increment variation in the course of the ages, *i.e.* regulate the complexion of increment variation (Kairiūkštis and Juodvalkis 1985). Therefore, not only the productivity of the habitat influences the increase in the diameter and height but it has crucial impact on the value of increment. That was the greatest correlation coefficient (0.73) while evaluating the mean diameter increment and habitat quality index (Kuliešis 1993). That was emphasized by many authors that wood with high properties comprises only in the dense stand (Antanaitis 1981, Kuliešis 1989).

As the results show the highest wood density (591 kg m$^{-3}$) was estimated in stands with $d_v$ = 0.3 cm per year, though in stands with $d_v$ = 0.7 cm per year – the smallest wood density (525 kg m$^{-3}$). While comparing pine wood strength properties it was estimated, that bending strength (92.67 MPa) and compression strength (82.48 MPa) of wood in pine stands with $d_v$ = 0.5 cm per year were the highest. It was estimated that wood density, bending strength and compression strength of pine trees from the analysed three $d_v$ groups have differed significantly.

The values of compression strength of analysed pine stands are high. Therefore this could be explained by the high content of latewood in the annual rings. Kapper (1954) has determined that compression strength depends on latewood percent (Table 2). Another reason is that the bottom logs of the stem were used in this research.

While determining pine wood strength, it was found that pine stands with the mean diameter increment in maximum *dv* of 0.5 cm per year have the higher strength properties. The obtained research data on the main parameters of pine stands with the good wood strength properties are compared with stand growth regularities data for the stand structure estimation. Though, the comparison provides the estimation of the growth singularities of pine stands with good wood strength properties. The main estimated parameters during the research and the data of the Lithuanian Forest Research Institute database for the pine stands with *dv* of 0.5 cm per year is compared with the dynamics of model stand yield (Kuliešis 1989), Lithuanian normal stand growth (Repšys *et al.* 1983) and the dynamics of the main stand parameters (Kuliešis 1993).

**Table 2.** Dependence of compression strength on latewood percent

| Latewood, % | 21 | 23 | 26 | 29 | 30 | 34 | 38 | 44 |
|---|---|---|---|---|---|---|---|---|
| Compression strength ‖, MPa | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 |

It is considered that pine wood has the most proper physical and mechanical properties when the stand stocking level is between 0.8 – 0.9. The same conclusion was given by Перелыгин (1963). In such pine stands the site index varies from III.3 to I.3 on Na and Nb forest sites, respectively.

The main parameters of the analysed 24 pine stands with the mean diameter increment in maximum *dv* of 0.5 cm per year were compared with the average height, average diameter at breast height and basal area of the model and normal stands. The dynamics of the main stand growth parameters are presented in Figures 2, 3 and 4. The comparison was done by site index (normal stand growth tables), by forest sites (dynamics of model stand yield tables) and by basic

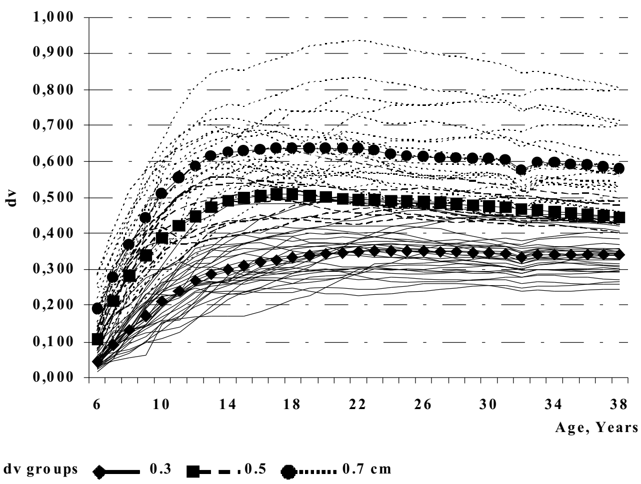


**Figure 2.** Arrangement of the mean diameter increments in maximum (*dv*) of dominating trees in different pine stands in different periods of age

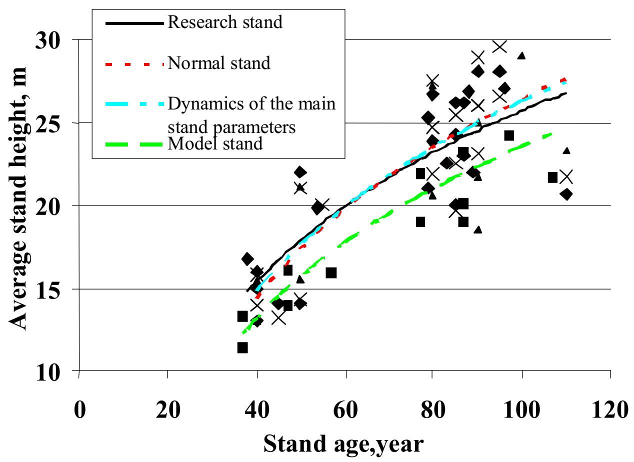


**Figure 3.** A comparison of the average height of pine stands (*dv* of 0.5 cm per year) and the data on height of the corresponding stand growth stage allowing for stand age

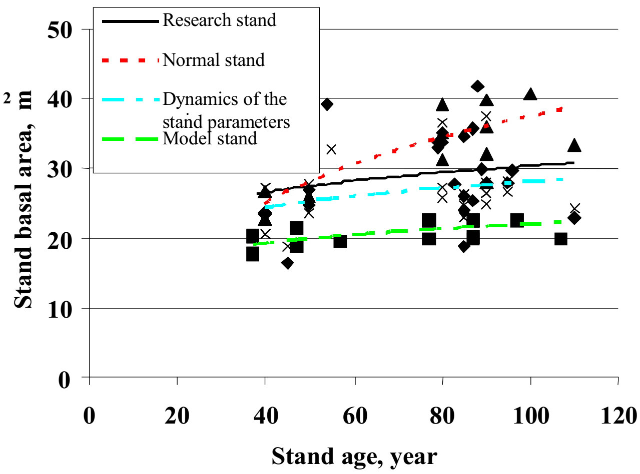


**Figure 5.** A comparison of the basal area of pine stands (*dv* of 0.5 cm per year) with the data on basal area of the corresponding stand growth stage allowing for stand age

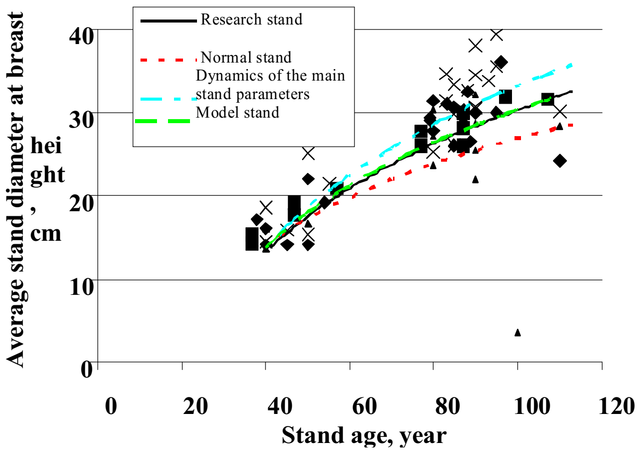


**Figure 4.** A comparison of the average diameter at breast height of pine stands (*dv* of 0.5 cm per year) with the data on diameter at breast height of the corresponding stand growth stage allowing for stand age

height (dynamics of the main stand parameters tables) allowing for the stand age.

The comparable parameters (average height, average diameter and basal area) of each research object at the respective age are slightly differed when compared with the parameters presented in the tables of the databases. The average parameter values for the relative table were obtained and the statistical parameters of regression were calculated.

The data in Figures 3 and 5 show that the analysed forest stands with higher wood strength properties has significantly higher average height and basal area as compared with the model forest stands. Meanwhile, only the values of the average diameters are comparable. Generally, the main parameters of the analysed forest stands with the mean diameter increment in maximum *dv* of 0.5 cm per year are comparable with the parameters of the model forest stands. The correlation coefficient represents the predicted comparability, for the average height correlation coefficient is $r = 0.97$, though with $mr = 0.02$, for the average diameters correlation coefficient $r = 0.92$ with $mr = 0.02$, and for the basal area correlation coefficient – $r = 0.74$ with $mr = 0.18$ (Kuliešis 1993). The peculiarities of the variation in parameter curves are also comparable due to the age. As it was assessed, the average stand diameters are starting to differ more with increasing age (Fig. 4). However, conformably to the average diameter the pine stands with the higher wood strength correspond to the good dynamics of the main stand parameters of the database tables. Moreover, the pine stands are in the intermediate place between the stands having average diameter foreseen in the regularities and described in the normal stand growth tables. Thus, the presented comparison of the main stand parameters shows that pine with the good wood strength is definitely required to grow following the considered parameters of the regularities and described in the dynamics of the main stand parameters tables.

## Conclusions

1. The smallest annual ring width and the biggest latewood percent were estimated in the wood of trees from stands with $d_v = 0.3$ cm per year, while the biggest annual ring width and the smallest latewood percent were estimated in the wood of trees from pine stands with $d_v = 0.7$ cm per year. The significant differences between all *dv* groups annual rings width

were determined, while latewood percent did not differ significantly between all *dv* groups.

2. The highest wood density was estimated in stands with $d_v$ = 0.3 cm per year and the lowest wood density in stands with $d_v$ = 0.7 cm per year. The bending strength and compression strength of wood from pine stands with $d_v$ = 0.5 cm per year were the highest.

3. The wood density, bending strength and compression strength of pine trees from the analysed three *dv* groups differed significantly.

4. It was considered that pine wood has the most proper physical and mechanical properties when the stand stocking level is between 0.8 – 0.9. In such pine stands the site index varies from III.3 to I.3.

A comparison of the main stand parameters shows that pine with the beneficent wood strength is required to grow following the considered parameters of the regularities and described in the tables of the dynamics of the main stand parameters.

## References

**Aleinikovas, M. and Grigaliūnas, J.** 2006. Differences of pine (*Pinus sylvestris* L.) wood physical and mechanical properties from different forest site types in Lithuania. *Baltic Forestry*, 12 (1): p. 9-13.

**Antanaitis, V.** 1981. Miško naudojimas [Use of forest]. Vilnius *Mokslas*, 198 p (in Lithuanian).

**Bitvinskas, T.** 1997. Centrinės Lietuvos klimatas ir medynų prieaugiai [Climate of Lithuanian central part and stands increments] . Rūšių tyrimai areale (1). Ekologinio optimumo zonos. Mokslo labdaros fondas, Vilnius. p. 9-11 (in Lithuanian).

**Grigaliūnas, J.** 1997a. The method of forest stand classification by growth types. *Baltic Forestry,* 3 (1): p. 10-13.

**Grigaliūnas, J.** 1997b. Lietuvos pušynų radialinių prieaugių kitimo vertinimo sistema [Evaluation system of Lithuanian pine radial increment variation]. Baigiamoji ataskaita, Kaunas-Girionys, 160 p. (in Lithuanian).

**Grigaliūnas, J.** 1998. Lietuvos pušynų augimo dinamika ir jos vertinimas [The dynamics and assessment of Scots pine stands growth in Lithuania]. Habilitacinio darbo santrauka. Kaunas-Girionys, 103 p. (in Lithuanian).

*ISO 3130:1975*. Wood — Determination of moisture content for physical and mechanical tests.

*ISO 3131:1975*. Wood — Determination of density for physical and mechanical test.

*ISO 3133:1975*. Wood — Determination of ultimate strength in static bending.

*ISO 3787:1976*. Method of testing in compressive strength parallel to grain of wood.

**Juknys, R., Venclovienė, J. and Jurkonis, N.** 2004. Aplinkos taršos įtaka medžių mirtingumui pušynuose. [Changes in Scots pine mortality under polluted environment]. *Miškininkystė*, 1 (55), p. 32-41 (in Lithuanian).

**Kairiūkštis, L. and Juodvalkis, A.** 1985. Etaloniniai medynai ir jų formavimas [Standard stand and it formatting]. Vilnius: *Mokslas*, 243 p. (in Lithuanian).

**Karpavičius, J.** 2005. Sausrų poveikis medžių radialiajam prieaugiui Pietų Lietuvoje [The drought influence on tree radial increment in South Lithuania]. Respublikinė mokslinė konferencija „Meteorologija ir hidrologija Lietuvoje: raida ir perspektyvos". Pranešimų medžiaga. Vilnius: Vilniaus universiteto leidykla, p. 50 – 51 (in Lithuanian).

**Kuliešis, A.** 1989. Medynų našumas ir jo panaudojimas [Stand yield and it employment]. Vilnius, 140 p (in Lithuanian).

**Kuliešis, A.** 1993. Lietuvos medynų prieaugio ir jo panaudojimo normatyvai [Forest yield models and tables]. Kaunas, 383 p. (in Lithuanian)

**Ozolinčius, R.** 1998. Lietuvos spygliuočiai: morfologinės struktūros transformacijos bei jas indukuojantys veiksniai. [Conifers in Lithuania: transformations of morphological structure and factors inducing them]. Monografija. Kaunas, „*Lututė".* 300 p. (in Lithuanian)

**Repšys, J., Kenstavičius, J. and Kuliešis, A.** 1983. Miško taksuotojo žinynas [Forest appraiser manual]. Vilnius, *Mokslas*, 268 p (in Lithuanian).

**Saladis, J. and Aleinikovas, M.** 2004. Pušų medienos fizinių ir mechaninių savybių kintamumas bei koreliaciniai ryšiai [Variability and correlation of physical and mechanical properties of pine wood]. *Miškininkyste,* 1 (55): 60-67 p. (in Lithuanian).

**Wodzicki, T., J.** 2001. Natural factors affecting wood structure. *Wood Science and Technology*, 35: 5 -26.

**Каппер, О. Г.** 1954. Хвойные породы [The Conifers].Москва, „*Гослесбумиздат* 303 с. (in Russian).

**Перелыгин, Л. М.** 1963. Древесиноведение [Wood science]. Москва, „*Гослесбумиздат*", 283 с (in Russian).

Received 15 March 2007
Accepted 17 May 2007

# ВЛИЯНИЕ СРЕДНЕГО ПРИРОСТА ПО ДИАМЕТРУ НА ФИЗИКО-МЕХАНИЧЕСКИЕ СВОЙСТВА ДРЕВЕСИНЫ СОСНЫ (*PINUS SYLVESTRIS* L.) В ЛИТВЕ

**М. Алейниковас**

*Резюме*

В статье представлены сравнения некоторых физических и механических свойств древесины сосны *(Pinus sylvestris* L.*)* в древостоях с различным типом роста. Данные были собраны на основе 9 пробных площадок. Сосновые древостои, выбранные для анализа древесины, имели относительно близкую структуру и характер идентичности роста древостоя. Для классификации доминирующих деревьев использован максимум среднего прироста (см*г$^{1}$) по диаметру*(dv)*. Согласно этому индексу, сосновые древостои были разделены на три *dv* группы: 0,3, 0,5 и 0,7 (см г$^{-1}$), при возрасте кульминационных приростов *(*$A_k$*)* с 15 до 36 лет.

Образцы были взяты из комблевой части ствола. На основании собраного материала были расчитаны: плотность, процент поздней древесины, ширина годичных слоев, прочность при статическом изгибе и прочность при сжатии вдоль волокон.

Было установлено, что плотность деревясины, прочность при статическом изгибе и прочность при сжатии вдоль волокон в проанализированных трех *dv* группах отличались значительно. Установлено, что древесина сосны имеет самые наилучшие физико-механические свойства при полноте в сосновых древостоев 0,8 – 0,9.

**Ключевые слова:** Сосна обыкновенная, максимум среднего прироста по диаметру, физико-механические свойства древесины