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Abstract of the Ph. D. thesis

Physical properties of the abnormal red heartwood and its effect on the usability

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I. Subjects and goals of research

One of the most dominant representative of the domestic forest property is the simply called “beech” , “common beech” (Fagus sylvatica). Beech is a characteristic specie of Central Europe, the area covered by beech slightly exceeds 100.000 hectares, from which the yearly gross felling reaches 600.000 m3.

Nearly 10% of domestic felling is given by beech, but this species has more importance in veneer and plywood industry (75%) and in sawmill industry (21%). From the viewpoint of the quality of beech wood material, the most important problem is the red heart according to the studied numerous scientific literature. The healthy, non fungi-infected beech with red heart is also called red beech in the woodworking practice.
The so called “grey”, or “star-shaped” red heart is already infected by fungi, not utilisable for industrial purposes. The most frequent criticism of experts interested and working in processing and trading against beech with red heart are as follows:

- not durable
- cracks easily
- drying is not even
- difficult to glue
- not appropriate from aesthetic viewpoint

and because of all these aspects hardly processable.

As the red heart affects 60-70% of log sortiments produced by end use felling, economic effects of this wood defect are not negligible. The real importance of the problem can be shown by the following example: Considering the price of the net 220.000 cu.m pro year beech logs to be 18.000 HUF/cu.m, it shows, that the realisation of **4.000.000.000 HUF/year** national product depends on this problem. So, it is not a minor matter how much percent of the value produced by forestries can be involved in further processing. The wood processing, taking the principles of environment protection into consideration – as a process – means the common utilisation of the log raw material and numerous secondary raw material basis made from that.

This scientific work deals exclusively with the further processing – and with its possibilities – of sawnwood from heartwood ,or containing partly heartwood, as a secondary raw material basis

originating from beech logs processed in sawmills; further on its main object is the material research giving the possibilities for this.
In the framework of this work, the phrases “red heartwood beech”, “red heartwood material” mean material with healthy red heartwood, except when expressively else marked.

The aim of this work is to disprove by its results those widespread delusions, that beech material with red heart is not suitable for furniture and interior raw material because generally

- its physical – mechanical properties are worse, than those of white beech
- it is less durable, than white beech
- it is not appropriate from aesthetic view

So, the objects of the author are summarised as follows:

- exploring the physical – mechanical properties of the beech wood containing red heart with the aim of establishing its industrial high quality processing,
- proving the usability of material of beech with red heart and proving its equality to white beech,
- creating new technological principals for beech processing sawmills using propositions established during research work

Conclusions as results from processing scientific literature:

1. From the viewpoint of our objects the literature of scientific antecedents can be summarised in three main groups as follows:

- process, reason, formation of red heartwood generally
- anatomy and types of red heartwood
- researches, experiments, observations regarding beech wood material containing red heartwood, sawnwood containing red heartwood, products made from beech containing red heartwood

2. Opinion of authors is equal in determining red heartwood, as follows: Red heartwood is a big size, irregularly shaped, abnormal discoloration of wood, boundary of which does not follow the annual ring. It occurs both in case of wood species having colour heartwood, and having not colour heartwood.

While it is easy to recognise in case of non-colour heartwood, it can be difficult in case of those having colour heartwood. However his difficulty is only apparent, as the real heartwood always follows annual rings, while red heartwood doesn't.

3. Furthermore most author agree in the opinion, that the developing of red heartwood is a kind of protection against the attack of fungi. This defence reaction is different in the cells having no internal function and in exterior tissue parts. Local patches of red heartwood develop in external tissue parts at the place of smaller mechanical damages (so called protective wood), while the common presence of air and fungi is necessary in internal tissues for the developing of red heartwood. It may also occur so, that air gets in the internal parts of the wood along whorl knots, or bigger damages.
4. Conditions of developing frost heartwood are also not clearly known. Some authors explain its development only with unusual cold, while others explain it also as a result of fungi infection at the same time. Also there is lack of agreement between authors regarding the reasons of forming star shaped heartwood. According to the opinion of some authors, the star shaped heartwood seems to be a problem of the root collar.
5. Also there is no agreement between authors in the question that the forming of red heartwood is a symptom showing growing tendency in accordance with the age of trees, or it has incoherence with the growing of the log diameter only. The effect of the site conditions is also disputed.
6. From the huge scientific literature of red heartwood it can be stated, that the opinions are not uniform regarding the forming of red heartwood. According to the point of view of the author, the following factors take part in the development of the red heartwood:
    - site conditions
    - false selection of sylviculture method
    - false selection of end use age
    - extreme weather conditions
    - different kinds of damages and fungi infections after that

In the mirror of the above statements this work makes sharp

difference between the fungi infected heartwood types and healthy heartwood types, free of fungi infection:

- Red heartwood (regular, nearly circle shaped heartwood), [generally healthy]
- Injury heartwood, or irregular heartwood [generally healthy]
- Frost heartwood, or grey heartwood, [generally infected]
- Star shaped heartwood,
- Pathologically wet [according to German scientific name: abnormal heartwood] [always infected]

As it can be seen from the above mentioned, only the healthy sortiments, free of fungi infection can be considered as suitable for further processing.
Physical–mechanical properties and aesthetical characteristics of these determine the further possibilities of processing. The scientific literature dealing with properties of beech with red heartwood is very poor. This fact can be traced back to the circumstance of being no market demand towards the products made from material containing red heartwood. Economic conditions have become suitable only in the last few years to let these kind of products to come on the market. The Wood Science Institute of the West Hungarian University has reached important result in the raw material research. The length of libriform fibres in the juvenile wood part of the beech shows interesting tendency. The measuring results of samples originating from different age groups (70; 90; 110 years) show, that the final length of libriform fibres is reached around the 20-25. annual ring. It means, that the well processable, uniform quality xylem reaches its properties relatively early, so product with uniform material quality can be made from the most part of the log. However it also means, that the part around the pith must be totally separated in the processing technology, as a wood material utilisable only for lower quality products.

After studying the scientific literature antecedents it can be stated, that earlier researches, dealing with heartwood and also with red heartwood of beech, mainly concentrated on the biological, sylvicultural connections of the question. They have done it hoping that determining the unambiguous reason (reasons) of development of red heartwood and by possible interventions during the sylviculture methods favourable result can be reached.

Unfortunately the findings born as results of researches don not contain unambiguous methods preventing developing of red heartwood. As a summary it can be stated, that previously no literature have been published which contained scientifically based and *practically* utilisable conclusions regarding utilisation of the material of beech with red heartwood.

II. Short summary of research work and methods

All examined material is originated from the area of ZALAERDDŐ Rt and have been processed in the Kerka Menti Fűrészüzem sawmill of ZALAERDŐ Rt. So the results represent the properties of the stock of an average domestic sawmill. The test material was available in the form of sawnwood (planks). The test cubes necessary for the certain tests have been produced so, that the test material with red heartwood and the test material of sound white beech have been made from the same plank, 50-50 pcs for each test. So the number of series was high enough to consider the received results serving reliable data series about characteristic values of the wood material. Forming of test cubes and processing of test have been made according to the concerning MSZ-EN Standard (Hungarian-European Standard), except cases, where no concerning standard exist. The following tests have been made:

1. Testing of physical-mechanical properties:
   - test of density,
   - test of shrinking and swelling,
   - test of compression strength,
   - test of shear strength,
   - test of bending strength,
   - test of bending modulus of elasticity,
   - test of impact-bending strength,
   - test of hardness.

2. Tests of application-technology:
   - test of abrasion-bearing,
   - artificial ageing tests,
   - tests of resistance against fungi,
   - drying tests,

- steaming tests,
- gluing tests,
- finishing tests.

Tests have been made according to MSZ-EN standards so, that a series of 50 pcs test cubes have been used to the determination of each tested property.
The test room of the Wood Science Institute did not satisfy the climatic demands of the standard tests, so correcting calculations have been made to the conditions of 12% moisture content. This, previously generally utilised method *do not influence the results in effect*. The bending and bending modulus of elasticity tests have been extended to product structural size materials as well, in order to clarify how do the industrially made products act in case of bending effect. In order to decide whether the differences of results received during the tests of white and red heartwood beech are important, or not, significance tests have been made, on 95% authenticity level, which is usual in the wood industry.
The aim of the scientific work is to give support based on research to experts working in the industry for the braver utilisation of beech timber with red heartwood in the widespread fields of wood industry. In order to back up this goal, such tests have also been made, which belong to the field of industrial research and development. The executed utilisation technology tests are organically built on the results of physical-mechanical tests; the results of these tests have to be evaluated together in many respects.

III. Results of research work

Physical-mechanical properties:

Evaluating the percentage value of dispersion [var.%] of test results of physical-mechanical properties it can be stated, that they meet the prescriptions of wood test standards. As an exemption of this, the received higher dispersion value in case of longitudinal shrinkage tests can be mentioned. Possibly it originated from the not satisfactory accuracy in the working of the test cubes. It is also worth to mention, that the similarly higher dispersion value of shearing and impact bending strength is originating from the test method.
However, generally the series of tests can be considered reliable.

	white beech	MwRH	grading of properties	significance
Density [g/cm^3]	0,712	0,723	MwRH is better	no significnce
Shrinkage				
Radial irány [%]	12,270	11,080	MwRH is better	sgnificance
Tangential irány [%]	6,040	5,850	MwRH is better	No significnce
longitudional irány [%]	0,470	0,510	**White is better**	No significnce
Volumetric [%]	18,050	16,780	MwRH is better	Significance
Compression strength [MPa]	65,380	62,540	**White is better**	**Signifikance**
Shear strength [MPa]	11,810	13,330	MwRH is better	Signifikance
Bending strength				
Standard [MPa]	120,100	115,830	**White is better**	no significnce
Produkt [MPa]	103,620	97,730	**White is better**	no significnce
Bending modulus of elasticity				
Standard [MPa]	13927,8	13345,5	**White is better**	**Signifiknce**
Produkt [MPa]	9.837,2	10249,7	MwRH is better	no significnce
Impact-bending strength [J/mm^2]	0,093	0,066	**White is better**	**Signifikance**
Brinell-Mörath Hardness				
End grain [MPa]	57,59	57,55	**White is better**	no significnce
Side grain [MPa]	25,07	27,72	MwRH is better	Signifikance
Tangential grain [MPa]	22,13	24,58	MwRH is better	Signifikance

MwRH=material with red hartwood

The above mentioned evaluation is made from the basic statistical data. In order to decide whether the differences of measured properties of beech with and without red heartwood are important, or negligible, a significance test have been made. During the test, a 95% acceptance level was utilised, which is generally accepted in the wood industry. So, if the reject level of compared values is less than 5%, the difference is significant with 95% probability, that is characteristic.
One of the aims of this work is to disprove those widespread delusions, that beech material with red heart is not suitable for furniture and interior raw material because “its physical – mechanical properties are worse, than those of white beech”.

The performed comparison tests of physical-mechanical properties of beech with and without red heartwood can give a basis to the utilisation of timber with red heartwood on fields, where it hasn’t been used up till now because of delusions. The summarised evaluation – based on the tests - in table form can be found on the next page. The two type marking in the two columns of the table is to serve the better visuality. The grey background in the column ”grading of properties” mark the properties, in which timber with red heartwood is better, the bold characters mark those, where white beech is better. In the column “significance” the grey background mark each properties, where timber with red heartwood is better, or white beech is not significantly better, than timber with red heartwood. So, in this column, the grey marking practically means, that relevant properties of timber with red heartwood are better, or practically equal to that of white beech.

For the industry, this chart means, that in cases, where the difference between the two materials is not significant, they have equal value in the everyday life. In cases where the timber with red heartwood has better properties, those properties can be considered as additional advantages in case of developments. In some cases white beech is significantly better, than that with red heartwood. In this field impact bending strength must be emphasised.

As a summary, evaluating the tests of physical-mechanical properties, it can be stated that there is no important and so basical difference between the examined properties of white

beech and beech with red heartwood, which could give reason to eliminate or push into the shadow the timber with red heartwood in the processing industry

Utilisation technological properties:

- Abrasion resistance

From the gained figures it can bee seen, that abrasion resistance of timber with red heartwood is better, than that of timber without red heartwood. In case of timber without steaming the abrasion of samples with red heartwood was 0,009 mm (32,63%) less, than that of timber without red heartwood. In case of steamed timber the abrasion of samples was 0,013 mm (39,65%) less, than that of timber without red heartwood. The abrasion of steamed material was higher in case of both the timber with and without red heartwood, but the differences were not significant.

- Artificial ageing

It can be stated, that 20 days artificial ageing considerably darkened and made inhomogene the originally light beech timber material. However the colour of the coloured heartwood became more homogene, and its red shade changed towards a yellowish shade. The matured part of the timber with coloured heartwood behaved the equally as the timber with white heartwood concerning cracking. The timber with sound heartwood showed favourable climate resistance.

- Resistance against fungi

It can be ascertained, that in the case of 2 types of test fungi according to standard (Trametes Versicolor and Coniophora) the resistance of the two kinds of timber against fungi did not show significant difference. But in case of nr. 1 test fungi (Gloephyllum) the resistance of the timber with red heartwood was much higher, than that of the white beech and nearly reached the total protection against fungi.

- Moisture absorption – drying

From the tests of moisture absorption it can be stated, that the red heartwood slightly decreases the speed of absorption, differences are significant in case of several points of time. *However taking the extent of differences into consideration,*

practically there is no difference between the speed of moisture absorption of beech timber with and without red heartwood, so according to results of laboratory tests, they can be dried together.

Examining the deformations of planks it can be stated, that there is no difference between the samples of beech with and without red heartwood. Also no significant difference can be found when examining the cracks caused by drying, and the remaining stresses (fork test). There is also no significant difference between the two materials in case of moisture content distribution in layers after drying.
The initial moisture content of the two kinds of materials was slightly different (1,84%), but at the end of the drying the end-moisture content was not significantly different. The difference between actual and target moisture content was relatively low: 0,99% in case of white beech, and 1,59% in case of beech with red heartwood. A part of results was documented in a drying record according to MSZ-08-0595-1989. According to this, drying of the white beech belongs to the category “A”, while drying of steamed beech belongs to the category “B”. It can be remarked, that in cases of grading viewpoints, where differences can not be proved, the classing into A and B categories is questionable, it means no real quality degrading. *As a summary of the results of drying tests it can be stated, that beech timber with and without red heartwood can be dried together, and the showed timetable assures satisfactory quality dried timber.*

- Steaming

Tests proved, that in case of steaming of beech the colour changing is resulted early, even in relatively low temperature. Permanent, longer lasting steaming does not result continuous colour changing. The test performed at 90°C, ascertained, that after two days of steaming, there is no considerable colour changing. So, by steaming, the colour can be varied only in a certain narrow region. In case of samples, where red heartwood and white parts exist together, steaming may result aesthetic colour harmony.

- Gluing

There is no significant difference in strength of gluing between

timber with and without red heartwood. Namely, products containing timber with red heartwood also can be glued with conventional water dispersion systems , with the same technologies utilised in case of beech without red heartwood. Steaming significantly decreased gluing strength, which can be explained by the decreasing of shear strength of the timber. *Taking the viewpoints of practical utilisation into consideration, it can be stated, that beech timber with and without red heartwood behave equally considering the gluing properties.*

- Finishing

Chemical bleaching is not suitable for the bleaching or colour equalisation of beech with red heartwood. Dark colour stains with same, or darker colour of red heartwood give satisfactory results. From the light colour stains, first of all the type containing water dispersion pigments (white stain) offers interesting effect on the beech timber with red heartwood. This solution can be recommended to finishing so called rustic (old fashioned) country furniture, bathroom furniture, wall covers, etc. In order to reach medium colour shades fashionable nowadays, acrylic dispersion water stains can be utilised, in case of not so high aesthatical demands, e.g. finishing children furniture (honey stain). Light and medium shade colour stains do not decrease the colour characteristics of timber with red heartwood – high contrast dark-light stripes, fields.

IV. Propositions

The finished work has led to the results as follows:

1. As a result of complex wood physical tests I have proved, that the (physical-mechanical) properties of beech timber with red heartwood, free from juvenile wood, are equal to those of the white timber parts.
   It can be stated, that considering the physical-mechanical properties, for the use in practice, *the timber of beech with red heartwood, free from juvenile parts, is better, or essentially of equal value than the timber of white beech*, except situations when exposed to dynamical load (e.g. tool handle) User in practice can utilise the timber of beech with red heartwood in his processing technology with this only restriction, and his product will be better, or practically equal value, from technical view as compared to the

product made of the white beech.

2. I have ascertained the advantages in utilisation technology due to abrasion resistance and hardness of timber with red heartwood versus the timber of white beech.

   It can be proved, that the beech timber with red heartwood has additional advantages against the timber of white beech considering the properties of abrasion resistance and hardness, as in case of these properties it is significantly better.
   This advantage can be increased by appropriate sawing and classification according to pattern of the wood parts containing red heartwood. So the user in practice will be able to produce better, more abrasion resistant product.

3. Durability tests have proven, that the durability of beech timber with red heartwood, which has considerable tyloses and additional material depositions, is better or equal to that of the white beech.

   Weather resistance, wearing tests have proven, that the abiotical durability of timber with red heartwood, having more dense tissue, is better, than that of the white beech.

   Test results undoubtedly have shown, that there is no difference between timber with and without red heartwood for the users in practice from the viewpoint of resistance against fungi. Both timber types are degraded by fungi – although in different extent and speed by fungi types. For the user the message of this proposition is that the source of danger is not the usage of the timber with red heartwood, but the existence of possibility of fungi infection regarding their product.

   Consequently, if we decide in the phase of product design, that a species with low resistance against fungi meets our demand, then the timber of beech with red heartwood can be used equally without any doubt.

4. I have proved, that the sorption isotherms of beech with and without red heartwood are nearly equal, so the two types of beech timber can be dried together.

   By laboratory tests of sorption and half industrial texts I have proven, that *the timber of beech with red heartwood can be dried together with the white parts and with the timber of white beech itself.* With suitable drying timetable I have ascertained, that this proposition described can also be utilised in the practice, under industrial circumstances, the targeted end moisture content certainly can be reached..

5. I have proved the colour equalising effect of the steaming and the limits of this effect. It can be proved, that *the colour difference of timber partly white and partly containing red heartwood can be decreased by steaming, in case of keeping suitable steaming parameters*. This is a fact proven by objective colour measurement. At the same time, the dark border characteristic of red heartwood can not be eliminated by steaming.

6. I have proved by laboratory tests and half industrial tests, that colour equalisation can be carried out only towards darker colour shade.

   Tests have proven, that timber partly or wholly containing red heartwood can not be bleached evenly – in a manner which is utilisable in the practice. It is also not possible to turn the dark parts evenly lighter by using other finishing chemicals, *thus the result of colour equalisation is realised always into a darker shade*. Consequently, the colour equalisation can only be realised towards the evenly darker shade, when light parts become unambiguously darker.

V.
The way to the utilisation of research results in practice, and proposed sawmill and by product processing technologies.

Experts working in practice concentrate only on the white part of the beech log during processing at present. Generally the log is cut around each side till the border of the red heartwood part, and then the remaining part is cut to 25 mm thick planks without any special aimed product..The great part of sawnwood originated from this method contain juvenile wood part as well. The juvenile wood part is the origin point of longitudinal cracks, so the whole produced sawnwood containing red heartwood seem to be a wrong quality timber.

The research work proves, that the timber with red heartwood, free from juvenile part – in suitable area of utilisation – can replace the material of white beech and becomes marketable good, because of its equal properties. Thus, from technology viewpoint the juvenile part and matured part of wood must be divided apart. By other words: in the processing, the whole mass of log must be counted equally. Already, in the beginning of the processing the aim of further processing of each part (juvenile part, part with red heartwood, white part) must be decided. So further steps of processing and/or marketing can be done with appropriate looking and equal quality sawnwood.

The sawmilling practice knows sawing methods suitable to selected demands since long time. From these some cases of the so called turning cut and the so called rift cut can be utilised ideally to process beech log with red heartwood, with regard to the greater average diameter of logs with red heartwood.

IV. Publications

Articles in periodicals abd other publications:

Apostol Tamás 1978: Rétegelt ragasztott fatartó gyártása Lengyelországban. [Production of laminated glued wood beam in Poland] Faipar 1978/8

Molnár, S.; Varga, F.; Tolvaj, L.; Fehér, S.; Németh, R.; Apostol, T.; Szoják, Pné. (2000): Kísérleti technológia álgesztes bükk fűrészáru továbbfeldolgozására.K+F zárójelentés ALK 00034/2000

[Experimental technology for the further processing of beech with red heartwood (End report of R & D)

Molnár, S., Németh, R., Fehér, S., Apostol, T., Tolvaj, L., Papp, Gy., Varga F. 2001: Technical and technological properties of Hungarian beech wood consider the red heart. Drevarsky Vyskum, 46/1 21-29.

Apostol Tamás 2004: Az álgeszt kialakulása a szakirodalom tükrében Faipar 2004/1
[Developing of red heartwood in the mirror of scientific literature]

Foreign language lecture published in a publication of international conference

Molnár, S., Németh, R., Fehér, S., Apostol, T., Várallyay, Cs. 2001: Modelling the Wood Processing Chain for Red Heart Beech. COST ACTION E 10 Wood Properties for industrial Use in Bordeaux, France

Lectures:

Apostol Tamás 1996: Hungarian organisations and the finance education, research and development in Forestry and Wood Science. Hungarian Wood Science Foundation. 1996. Nov.11. University Canterbury New Zealand

Apostol Tamás 1999: Néhány gondolat az alföldi fenyők tulajdonságairól és felhasználási lehetőségeiről. Soproni Egyetem 1999.11.04.
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[Development, anatomical and physical properties of red heartwood. PhD examination, West Hungarian University, Sopron