

## EFFECT OF THE KIND OF LOW-TEMPERATURE INITIATOR OF POLYMERIZATION ON THE COURSE OF POLYMERIZATION PROCESS OF STYRENE IN WOOD AND ON SELECTED LIGNOMER PROPERTIES

*Maciej Ławniczak*

Chair of Mechanical Wood Technology Agricultural Academy, Poznań

The influence of various systems of polymerization initiating substances containing low-temperature initiators on the course of polymerization of styrene in birch wood during its hydrothermal treatment is discussed. Changes of temperature inside the produced lignomer and also its dimensional stability and static bending strength at  $8 \pm 2\%$  moisture content and maximum moisture content were observed.

### GENESIS AND PURPOSE OF RESEARCH

Taking into account needs of practice relating the solution of the problem of simultaneous improvement of wood properties and prolongation of its service life, the technology of creating wood-polymer composites has been developed. This technology – in accordance with material engineering – allows for combining together most advantageous properties of one of the ancient natural materials viz. wood with properties of contemporary materials such as plastics.

The technology of making wood-polymer composites consists in the introduction into wooden tissue the least chemical particles in the form of monomers or premonomers and then their polymerization in situ [24, 25]. In consequence of these fundamental technological operations, we obtain a material composite characteristic by substantial improvement of strength properties and deprival of fundamental defects of wood. This applies not only to wood but, first of all, to the used plastic material. It is because cellulose framework, being in itself a natural polymer, is fortifying used plastics in the same way as plastics are fortified in practice by means of glass fibres.

Investigations initiated in the early 60s revealed existing predispositions for creating wood-polymer composites using chemical compounds having one or more

bonds and called vinyl monomers which can be polymerized into solid polymer by means of free radicals. This polymerization is decidedly better than polycondensation reactions caused by acid or alkaline catalysts and resulting in obtaining a product which must be removed from final composite as for example water. Acid and alkaline catalysts used in polycondensation processes are also degrading cellulose chains and bring about brittleness of the composite.

Combination of wooden substance with plastics can be obtained by means of free radicals using two methods of polymerization viz. radiation polymerization or thermal-catalytic polymerization. The practice of last two decades indicates that radiation polymerization method, because of the necessity of using high energy sources installation which calls for large investments and necessity of employing highly-qualified personnel and because of using complicated and long-time treatment technology, did not gain broad application in practice with the exception of the United States of America where these investments were sponsored by the Atomic Energy Commission.

The application of thermal-catalytic polymerization technology in the production of wood-polymer composites was meeting in the first period a number of obstacles such as, among others, the loss of the large amount of monomer expelled from wooden tissue during the period of exothermic process of their polymerization [23, 26]. Resulting presence of monomer in air can create explosion hazard.

Therefore, in case of using the thermal-catalytic polymerization process it is necessary to bring heat to wood-monomer system at the initiating stage, but at the moment of starting the polymerization process the flow of heat is reversed because the temperature of forming composite rapidly rises as the flow of heat in wood is much slower than the rate of heat generation.

In 1971 the invention was made which helped to eliminate or at least to limit mentioned above imperfections of thermal-catalytic polymerization of monomers in wood. The substance of this invention consists in the application of initiating substances having different half-periods of disintegration, followed by thermal treatment in liquid medium, in the process of polymerization of introduced into wood monomers [9]. Simultaneous application of two or more polymerization initiators is intended to initiate the process of styrene polymerization not at once but by degrees in dependence on the action of particular initiators characteristic by different half-period of disintegration temperature. Initiator of the lowest half-period disintegration temperature turns the liquid monomer into gel the viscosity of which increases preventing its exudation from wood, particularly at the peak of polymerization process when temperature often is exceeding the boiling point of monomer.

Heating in the liquid medium during the first period of polymerization process, is intended to heat wood impregnated with monomer gradually up to the temperature of half-disintegration of polymerization initiators in results of which initiation of polymerization begins as an exothermic reaction. The process of monomer polymerization is accompanied by the release of considerable amount of heat. Excessive heating of wood can injure the structure of wood and even initiate its thermolysis. Therefore, the liquid medium used for heating wood at the beginning of monomer

polymerization process, is also acting as a cooling medium dispersing the excessive heat released by exothermic reaction occurring in further steps of polymerization thus cooling the treated wood. The amount of released heat depends in the first place on the amount of monomer present in wooden tissue. The rate of heat release can be to a certain degree controlled and regulated by the selection of proper kind and amount of initiating substance therefore by the amount of available free radicals.

The amount of occurring free radicals depends on the temperature which is a deciding factor in the rate of half-disintegration of polymerization initiators, so with the increase of temperature the amount of free radicals rapidly increases which, in turn, increases the temperature inside wood until reaching a maximum corresponding the peak of exothermic reaction of polymerization process. It is necessary to add here, that for making wood-polymer composites on technical scale, only stabilized monomers should be used which are containing polymerization inhibitors and it must be remembered that wood itself contains polymerization inhibitors the quality and quantity of which is depending on the kind of wood. In connection with this, a part of occurring free radicals is used for elimination of these inhibitors. Only when inhibitor is eliminated from both monomer and wood, the initiation of monomer polymerization process is started.

From gained information about the course of monomer polymerization in wooden tissue while using the thermo-catalytic technique it can be gathered that the deciding role in the process is played by the kind and amount of initiating substance and conditions of heat treatment. Proper selection of these factors decides about the quality of produced wood-polymer composites.

Research work conducted in our Institute and continued at the Chair of Mechanical Wood Technology, Agricultural Academy, Poznań, from over 15 years, is aimed at the development of a simple and most economical technology of wood-polymer composites production. This research is, in the first place concerned with the proper selection of the right kind, system, and amount of initiating substances and thermal treatment parameters in wood-polymer composites production taking into consideration also the kind of wood used for that purpose [4 - 8, 10 - 22].

It can be seen from up to now gained experience, that styrene is a most predestined monomer for the production of wood-polymer composite when using thermo-catalytic polymerization technique [3]. At the present state of industrial development all over the world and application of plastics, a distinct surplus of styrene can be observed which, in the opinion of specialists, will be growing. Therefore, there is now an unique opportunity of using this priceless product of chemical industry for the production of wood-polymer composites.

The quality of produced wood-polystyrene composite named here lignomer, is decided, in the first place, by the selection of proper composition and quantity of initiating substance. The kind and quantity of used initiators are also determining the time of styrene polymerization in wood and, therefore, the production capacity of plant and devices.

Effect of the kind and concentration of initiating substances in the process of styrene polymerization depending on conditions of thermal treatment was the subject

of our research activity since over 10 years [4, 5, 7, 8, 10 - 21]. The result is: evident improvement of produced lignomer quality without any trace of free styrene and a triple reduction of the time of styrene polymerization in wood from 15 to only 5 hours.

The speed of polymerization process is decided also, apart from conditions of thermal treatment, by the selection of the kind and quantity of used initiators having relatively low temperature of half-disintegration period in relation to the rest initiating substances.

In connection with this, it was regarded as a necessity to carry out research work aimed at the determination of the effect of two newly developed polymerization initiators on the course of the process of styrene polymerization in wood and on selected properties of obtained lignomer. The practical goal of these investigations was the usage already mentioned low-temperature polymerization initiators in the production of wood-polymer composites. Intermediate goal was an improvement of produced lignomer properties and reduction of time needed for styrene polymerization in wood.

## METHODOLOGY AND MEANS OF INVESTIGATION

### EXPERIMENTAL MATERIALS

#### Kind of wood

Birch wood was used because of its density and good impregnability. In order to secure the homogeneity of experimental material, samples of  $50 \times 50 \times 170$  mm dimensions were prepared from one bolt and the same layers of growth rings. Prepared in this way samples were then conditioned until attaining  $13 \pm 2\%$  moisture content.

#### Kind of monomer

In accordance with up to now obtained results the styrene monomer was used containing hydrochinone inhibitor in the amount of 300 mg/kg and produced by Oświęcim Chemical Works. The styrene monomer was characterised by  $0.906 \text{ g/cm}^3$  density at  $20^\circ\text{C}$  and contained 99.67% of pure styrene and 0.1% ethylbenzene in its composition.

#### Kind of polymerization initiator

In selection of polymerization initiator it is vital to be guided by its technological characteristics that is: the content of active oxygen, time of half-life, activation energy, critical temperature of disintegration and the kind and amount of thermal disintegration products.

Two recently developed in Poland polymerization initiators were used during reported investigations viz. initiators denoted by symbols ABWN and NWEH-70. Apart of these, known already benzoyl peroxide (NB) and cumene hydroperoxide (WNK) were also used.

## Composition of polymerization initiators

Three of mentioned above initiating substances having compositions shown in Table 1 were used. Selection of proper quantitative composition was based on results of previous investigations where it was found that the quantity of initiating substance in relation to stabilized styrene should approximate up to 1, 2 part per 100 parts by weight measure.

Table 1

Initiators mixtures used to polymerization  
Zestawienie składu inicjatorów polimeryzacji

Mixture number Nr zestawu	Initiators Rodzaj inicjatora			
	NB	WNK	ABVN	NWEH-70
	in weight parts per 100 w.p. of styrene w częściach wagowych na 100 cz.w. styrenu			
1	0.6	0.3	0.3	—
2	0.6	0.3	—	0.3
3	0.6	0.3	0.1	0.1

## PREPARATION OF IMPREGNATING SOLUTION

Used in particular variants of experiments, sets of initiating substances were added to styrene in the following sequence: cumene hydroperoxide (WNK), benzoyl peroxide (NB) and, after mixing these with styrene using mechanical stirrer, one or simultaneously two initiators belonging to low-temperature group were added to the mixture which was once more homogenized to form an impregnating solution.

## METHOD OF IMPREGNATION

Samples of birch wood of  $50 \times 50 \times 170$  mm dimensions and  $13 \pm 2\%$  moisture content were placed in autoclave from which air was then evacuated by means of vacuum pump. After evacuation of air from wood, impregnating solution composed of styrene and polymerization initiators has been introduced into autoclave. After one hour time samples of wood were removed and the degree of impregnation was determined by comparison of sample weight before and after impregnation.

## METHOD OF THERMAL TREATMENT

The thermal treatment of impregnated with styrene birch wood samples has been carried out in accordance with the developed technology. Two variants of heat treatment were used:

A. at temperature from 80 to 100°C,

B. at temperature from 90 to 105°C,

in each case with two periods of heat treatment namely 150 and 240 seconds. In order to measure the temperature inside wood during its thermal treatment, an iron-constantan thermocouple was installed and sealed with sawdust and epoxy resin in the hole of 1.5 mm diameter and 25 mm depth made in the middle of the

sample. Temperature has been recorded by means of compensating recorder of MKV type at the speed 6 cm/h of compensating tape. The frequency of recording was 5 seconds.

#### METHOD OF ASSESSING THE COURSE OF STYRENE POLYMERIZATION PROCESS

Measurement of temperature changes inside wood in the period of heat treatment was accepted as a criterion of styrene polymerization process assessment depending on the kind of low-temperature polymerization initiator used. Analysis of temperature changes occurring inside forming itself wood-polystyrene composite during the period of its thermal treatment allows for the establishment of the beginning of initiation, polymerization process at the temperature peak as an effect of exothermic process of styrene polymerization in wood, and time of treatment before the occurrence of highest temperature.

#### CRITERIA OF THE ASSESSMENT OF FORMED LIGNOMER QUALITY

The dimensional stability, inability static bending strength at  $8 \pm 2\%$  moisture content and water saturation point are accepted as criteria of the quality of lignomer formed with the application of low-temperature polymerization initiators depending on their kind and conditions of thermal treatment. Proper determinations were performed in the way formerly described [14].

#### RESULTS OF EXPERIMENTS AND THEIR ANALYSIS

##### EFFECT OF THE KIND OF LOW-TEMPERATURE POLYMERIZATION INITIATOR AND CONDITIONS OF THERMAL TREATMENT ON THE COURSE OF STYRENE POLYMERIZATION IN WOOD

Effect of the kind of low-temperature polymerization initiator and conditions of heat treatment on the course of temperature changes inside the forming birch wood-polystyrene composite during thermal treatment depending on the composition of initiating substance is presented in Fig. 1. It can be seen from this figure, that polymerization of styrene in birch wood is accompanied — as was to be expected — by the emission of heat which is manifesting itself in the first period of sample heat treatment, by temperature rise inside wood. During initial period of heat treatment, the rise of temperature inside wood can be observed in effect of which polymerization initiators are disintegrated into free radicals which firstly neutralize present in styrene inhibitor and later initiate styrene polymerization process manifested by rapid temperature rise, rapidity of temperature peak occurrence and its value depending on the kind of used low-temperature polymerization initiator as a component of applied initiating substance. The rate of the course of styrene polymerization in wood is depending also on the heating medium which was water in this case. When water of initial temperature is higher than  $10^\circ\text{C}$ , for instance of  $90^\circ\text{C}$  was used, the temperature peak appeared sooner and was by about  $10^\circ\text{C}$  higher.

After occurrence of maximum temperature as an effect of heat emission in the process of styrene polymerization in wood, the temperature dropped until it was even with the temperature of the heating medium.

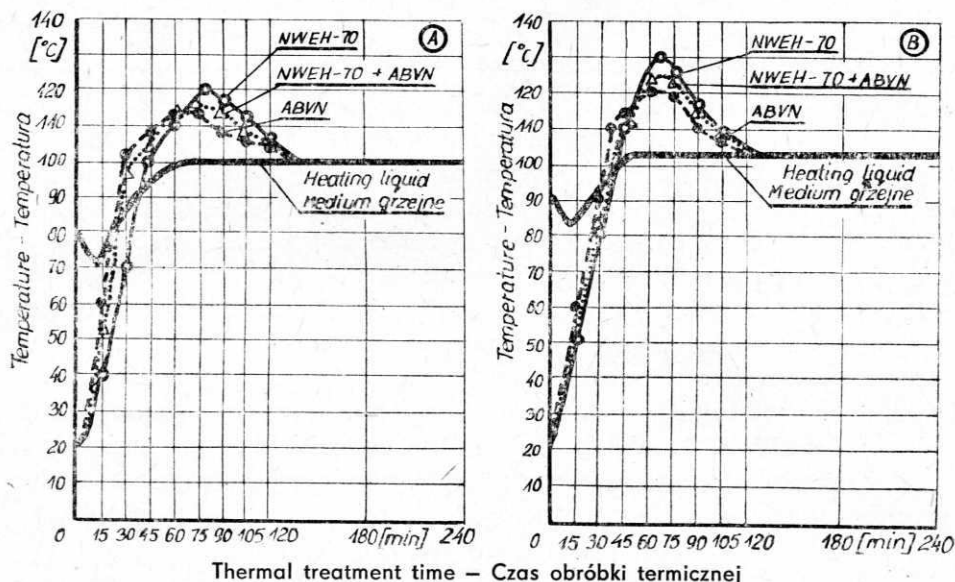


Fig. 1. Effect of kind of low-temperature initiator on temperature changes within the formed composite material birch wood – polystyrene during the thermal treatment: A – 80 - 100°C; B – 90 - 105°C

Rys. 1. Wpływ rodzaju niskotemperaturowego inicjatora polimeryzacji na przebieg zmian temperatury wewnątrz tworzącego się kompozytu drewno brzoazowe – polistyren w następstwie termicznej obróbki o temp.: A – 80 - 100°C; B – 90 - 105°C

Curves presented in Fig. 1 are demonstrating that in case of using NWEH-70 in the composition of initiating substance a distinctly higher temperature peak is occurring which attests to more speedy course and conclusion of styrene polymerization in wood process than in case of ABVN. It is necessary to add here that during block polymerization exothermic maximum occurs when polymerization process is already concluded.

After occurrence of temperature peak which is an aftermath of styrene polymerization process, when the initiating substance containing NWEH-70 is used, a rapid drop of temperature inside wood is taking place. However, when the initiating substance is containing ABVN a distinct temperature peak does not occur and maximum temperature maintains itself several minutes on the same level. Application of initiating substance containing simultaneously NWEH-70 and ABVN causes that the temperature inside wood is reaching intermediate values of those observed when one of previously mentioned low-temperature initiators is used.

Generalizing all these observations it can be said that in case of using NWEH-70 in the composition of polymerization initiators, inhibitors present in styrene and wood are undergoing slower neutralization, while styrene polymerization in wood takes place more quickly and ends more early than in case of using ABVN.

EFFECT OF THE KIND OF USED LOW-TEMPERATURE POLYMERIZATION INITIATOR AND CONDITIONS OF THERMAL TREATMENT ON THE QUALITY OF PRODUCED LIGNOMER

Dimensional stability

Dimensional stability of lignomer produced with the application of initiating two kinds of low-temperature polymerization initiators (subjected to investigation) was determined on the basis of moisture induced deformations occurring during soaking of samples in water of  $20 \pm 2^\circ\text{C}$  temperature.

Results of these experiments are presented in Fig. 2 - 3. From curves depicting the dynamics of birch lignomer swelling, in dependence of used low-temperature initiators, apart from conditions of thermal treatment, it can be seen that the least deformation after soaking in water was observed in lignomer produced with the application of NWEH-70 initiator. In case of using ABVN in the composition of initiating substance it was found that produced lignomer swelled more in water than lignomer produced with the application of NWEH-70 polymerization initiator.

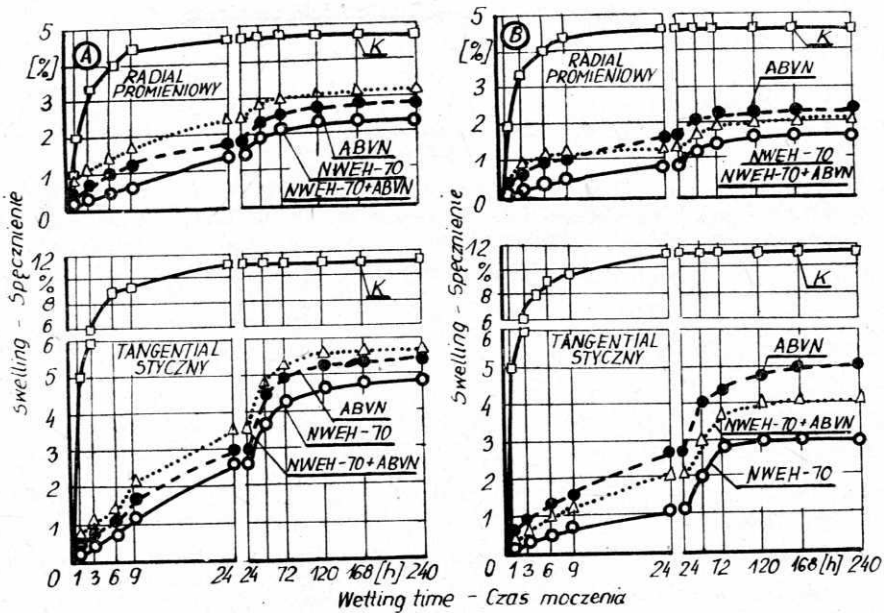


Fig. 2. Effect of kind of low-temperature initiator contained in initiators mixture on swelling of birch lignomer obtained by the thermal treatment during: A - 150 min at 80 - 100°C; B - 240 min at 80 - 100°C

Rys. 2. Wpływ rodzaju niskotemperaturowego inicjatora polimeryzacji w składzie substancji inicjującej na spęcznienie wytworzonego lignomeru brzozonego przy zastosowaniu obróbki termicznej przez: A - 150 min do 80 - 100°C; B - 240 min do 80 - 100°C



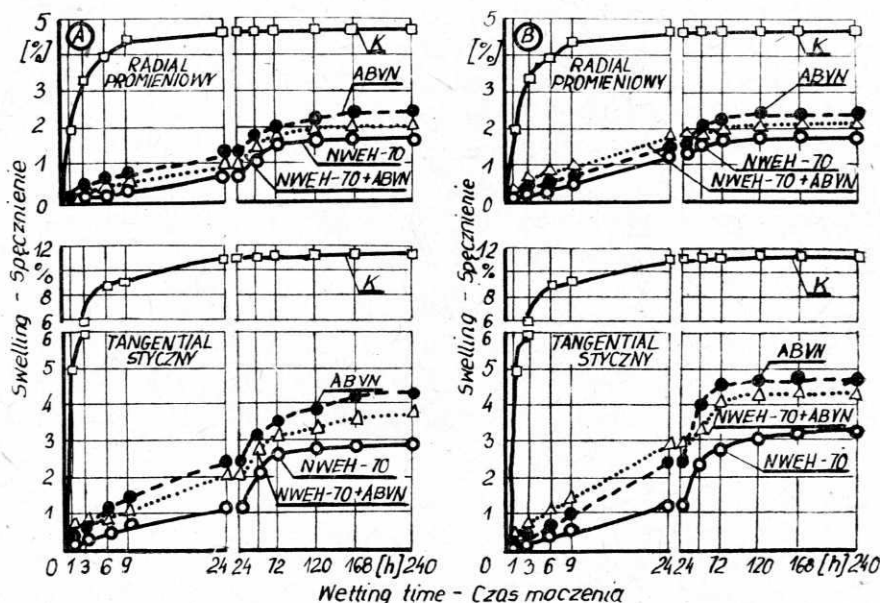


Fig. 3. Effect of kind of low-temperature initiator contained in initiators mixture on swelling of birch lignomer obtained by the thermal treatment during: A – 150 min at 90 - 105°C; B – 240 min at 90 - 105°C

Rys. 3. Wpływ rodzaju niskotemperaturowego inicjatora polimeryzacji w składzie substancji inicjującej na spęcznienie wytworzonego lignomeru brzoazowego przy zastosowaniu obróbki termicznej przez: A – 150 min do 90 - 105°C; B – 240 min do 90 - 105°C

Conditions of thermal treatment decidedly affected dimensional stability of lignomer produced with the application of the same sets of polymerization initiators. Lignomer made with the application of heat treatment in the range of 90 - 105°C was characteristic by clearly lesser deformations in comparison with lignomer with the application of heat treatment at 80 - 100°C temperature range. Elongation of heat treatment time up to 240 minutes affected favourably lignomer dimensional stability particularly when the temperature of heat treatment was 80 - 100°C. Effect of treatment time on the swelling of lignomer produced with the application of NWEH-70 polymerization initiator was not observed during soaking in water.

In case of using initiating substance containing both NWEH-70 and ABVN polymerization initiators, the produced lignomer exhibited moisture-induced deformations either slightly larger or slightly lesser in comparison with lignomer produced with the application ABVN polymerization initiator, depending on conditions of thermal treatment used. Higher temperatures and longer time of heat treatment affected favourably the dimensional stability of lignomer produced with simultaneous addition of NWEH-70 and ABVN initiators to styrene.

Summarizing the actual analysis of obtained research results aimed at the determination of the effect of the kind of used polymerization on the dimensional stability of birch lignomer it can be said, that the application of NWEH-70 initiator in the

composition of initiating substance insures obtainment of lignomer of better dimensional stability than in case of using ABVN initiator. Application of lower temperature and shorter time of heat treatment when NWEH-70 polymerization initiator is used does not decrease the dimensional stability of lignomer in the same degree as in case of application of ABVN initiator. This can be explained by higher rate of the polymerization process of styrene in wood and higher maximum temperature peak occurring inside wood which additionally affect advantageously the process of polystyrene grafting on the wooden substance [1].

### Imbibition

Effect of the kind of low-temperature polymerization initiator on the imbibition of produced birch lignomer is presented in Table 2. From data presented there it can be concluded that the kind of initiating substances used for producing lignomer

Table 2

Effect of initiators mixture composition and thermal treatment conditions on imbibition of birch lignomer  
Wpływ rodzaju składu substancji inicjującej i warunków obróbki termicznej na nasiąkliwość lignomeru brzoźowego

Treatment conditions Warunki obróbki		Initiators Rodzaj inicjatora				Soaking time (h) Czas moczenia (godz)		
Temperature Temperatura °C	Time (min) Czas (min)	NB	WNK	NWEH-70	ABVN	6	24	240
		in weight parts per 100 w.p. of styrene w cz.w. na 100 cz.w. styrenu				Imbibition in % of lignomer weight Nasiąkliwość w % masy lignomeru		
80 - 100	150	0.6	0.3	0.3	—	4	9	20
		0.6	0.3	—	0.3	6	12	20
		0.6	0.3	0.1	0.1	5	11	19
	240	0.6	0.3	0.3	—	5	6	18
		0.6	0.3	—	0.3	5	8	19
		0.6	0.3	0.1	0.1	5	7	20
90 - 105	150	0.6	0.3	0.3	—	3	6	14
		0.6	0.3	—	0.3	3	7	16
		0.6	0.3	0.1	0.1	3	6	15
	240	0.6	0.3	0.3	—	3	5	12
		0.6	0.3	—	0.3	3	6	15
		0.6	0.3	0.1	0.1	4	7	14

does not clearly affect its imbibition during soaking in water. Maximum imbibition of birch wood was 120%, therefore the imbibition of produced lignomer was over six times lower.

### Static bending strength

Effect of the kind of low-temperature polymerization initiator on obtained lignomer static bending strength is presented in Table 3. Numbers presented there are showing that, irrespective of used conditions of thermal treatment, produced lignomer was characteristic by clearly higher static bending strength when NWEH-70 initiator

Table 3

Effect of kind of low-temperature initiator and thermal treatment conditions on the static bending strength of the lignomer  
 Wpływ rodzaju inicjatora niskotemperaturowego na wytrzymałość wytworzonego lignomeru podczas zginania statycznego w zależności od warunków obróbki termicznej

Thermal treatment conditions Warunki obróbki termicznej time - czas temperature temperatura	Initiator Rodzaj inicjatora				Content of Zawartość		Loss of styrene Ubytek styrenu %	Samples humidity when investigated Stan próbek w chwili badania												
	NB		WKNK		monomer			w = 8 ± 2 %		maximum wet maksymalnie mokre		V								
	ABVN	NWEH-70	monomer	polimer	MPa	%		MPa	%	MPa	%	MPa	%							
	Content in w.p. per 100 w.p. of styrene Zawartość w cz.w. na 100 cz.w. styrenu				in % of wood weight w % masy drewna															
150 min 80° - 100°C	0.6	0.3	0.3	-	76	73	4.9	126	148	36.1	28.7	73	197	11.5	15.7					
	0.6	0.3	-	0.3	81	81	0.0	152	179	24.7	16.3	98	265	6.9	7.8					
	0.6	0.2	0.1	0.1	77	77	0.0	161	189	16.6	11.5	106	286	17.3	16.3					
240 min 80° - 100°C	0.6	0.3	0.3	-	82	77	5.4	133	156	18.2	13.7	92	249	11.4	12.4					
	0.6	0.3	-	0.3	84	84	0.0	157	185	16.6	10.6	104	281	7.5	7.2					
	0.6	0.2	0.1	0.1	83	81	2.2	169	199	12.7	7.5	113	305	7.4	6.5					
150 min 90° - 105°C	0.6	0.3	0.3	-	78	72	8.7	135	159	15.2	11.3	78	211	9.4	12.0					
	0.6	0.3	-	0.3	76	76	0.0	165	194	16.5	10.0	105	284	12.2	11.6					
	0.6	0.2	0.1	0.1	81	79	2.3	177	208	17.4	9.8	115	311	7.4	6.4					
240 min 90° - 105°C	0.6	0.3	0.3	-	83	71	14.1	159	187	22.8	14.3	95	257	7.6	7.2					
	0.6	0.3	-	0.3	82	82	0.0	175	206	13.0	7.4	110	297	9.7	8.8					
	0.6	0.2	0.1	0.1	77	73	5.7	180	212	16.3	9.1	114	308	7.5	6.6					
-	-	-	-	-	-	-	-	85	100	9.4	11.1	37	100	2.8	7.6					

was used than in case of using initiating substance containing ABVN initiator. Lignomer produced with the simultaneous application of both mentioned above polymerization initiators that is ABVN and NWEH-70 featured the highest value of static bending strength.

Time of thermal treatment affected the strength of lignomer particularly in case of using ABVN polymerization initiator in its production. In such case 150 minutes long treatment time must be regarded as decidedly too short one. Prolongation of that time to 240 minutes distinctly improved static bending strength of produced lignomer.

Thermal treatment at higher temperature, that is 90 - 105°C, clearly affected advantageously strength properties of produced lignomer particularly in case of using shorter time of treatment (150 minutes).

During the thermal treatment of birch wood impregnated with styrene in case of the application of initiating substance containing ABVN polymerization initiator it was observed that the loss of styrene was higher the higher was treatment temperature and the longer was time of heat treatment. In performed experiments when ABVN initiator has been used in the composition of initiating substance, this loss amounted to 4.9 - 14.2% of styrene mass. On the other hand, in case of using both kinds of discussed initiators at the same time, styrene loss during its polymerization was lower amounting to 2.2 - 5.7%.

This can be explained by the fact that polymerization initiator of the „Vazo” type containing nitrogen in its composition – ABVN in our case – undergoes disintegration with the rise of temperature releasing in the process free nitrogen from its composition in the form of gas. For example, from 1 g of ABVN present in 200 g of styrene, about 145 cm<sup>3</sup> of nitrogen is released at 90°C temperature and this volume increases with the rise of temperature. Nitrogen released during the disintegration of ABVN initiator undergoes a partial confinement in the very sticky monomer-polymer mixture [23], creating free voids while the rest of it is expelled outside squeezing out on the way a part of styrene monomer which then is polymerized in water solution used for thermal treatment. This is leading to the supposition that the phenomena observed during styrene polymerization in wood with the application of ABVN initiator are detrimentally affecting strength properties of obtained lignomer because of lower polystyrene content and somewhat porous structure.

Static bending strength of lignomer produced with the application of ABVN polymerization initiator and determined at the maximum wet state when 150 minutes time of thermal treatment was used is by about 70% lower in comparison with lignomer produced with the application of NWEH-70 initiator. In search of analogy between the static bending strength of lignomer, the kind of used low-temperature initiator in the composition of initiating substance and temperature of exothermic reaction peak of styrene polymerization process in wood, it can be supposed that at the temperature above 120°C a partial depolymerization of some natural polymers of low degree polymerization present in wood substance is taking place and, therefore, it seems that this fact favors the copolymerization and occurrence of cross-bonding linking synthetic polymer with woody substance.

This hypothesis is confirmed by research work of Z. Czechowski and R. Zakrzewski [1] which demonstrated that in alder lignomer produced at 132°C temperature peak of styrene polymerization as much as 12.7% of polystyrene was permanently bonded with holocellulose. On the other hand, when exothermic reaction temperature peak in the polymerization process was amounting to 108°C, only 4.5% of polystyrene was permanently bonded with holocellulose. It can be deduced from that, that higher static bending strength of lignomer produced with the presence of NWEH-70 in the initiating substance is a consequence of higher temperature peak occurring inside wood and favoring polystyrene copolymerization with wood substance, advantageously affecting the properties of produced birch wood-polystyrene composite.

### CONCLUSIONS

On the basis of performed analysis of obtained investigation results the following conclusions can be made:

1. Application of NWEH-70 in the composition of substance initiating styrene polymerization in birch wood brings about more speedy course of polymerization process than in case of using ABVN initiator. In the presence of NWEH-70 the temperature peak is occurring earlier.

2. Application of liquid heating medium of 90°C initial temperature for thermal treatment of styrene impregnated wood with addition of discussed polymerization initiators, reduces somewhat the time of styrene polymerization in relation to the time needed for that purpose when heating medium of 80°C temperature is used.

3. Lignomer produced with the application of NWEH-70 in the composition of initiating substance featured higher dimensional stability in comparison with lignomer produced with the application of ABVN initiator. When NWEH-70 was used, conditions of heat treatment were less affecting lignomer dimensional stability in comparison with ABVN usage.

4. Used in experiments low-temperature polymerization initiators were not clearly affecting the imbibition of produced lignomer.

5. Lignomer produced with the application of initiating substance containing NWEH-70 polymerization initiator featured considerably higher static bending strength without respect to applied conditions of thermal treatment, then lignomer produced with the application of initiating substance containing ABVN initiator. Simultaneous application of ABVN and NWEH-70 initiators of polymerization process allowed for obtaining lignomer of the highest static bending strength.

6. The thermal treatment at higher initial temperature, namely in the range of 90 to 105°C showed clearly advantageous effect on lignomer properties particularly in case of using short times of treatment.

7. Presence of ABVN in the composition of initiating substance caused the expelling of styrene from wood progressively with temperature rise and prolongation

thermal treatment time. This phenomenon was caused by the emission of nitrogen in the form of gas during the time of ABVN disintegration into radicals initiating the process of polymerization.

Praca wpłynęła do Redakcji w marcu 1986 r.

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#### WPLYW RODZAJU NISKOTEMPERATUROWEGO INICJATORA POLIMERYZACJI NA PRZEBIEG PROCESU POLIMERYZACJI STYRENU W DREWNI I WYBRANE WŁAŚCIWOŚCI LIGNOMERU

##### Streszczenie

O przebiegu procesu polimeryzacji, poza warunkami obróbki termicznej, decyduje dobór rodzaju i ilości inicjatorów.

Celem badań było stwierdzenie wpływu dwóch niskotemperaturowych inicjatorów polimeryzacji, oznaczonych symbolami ABVN i NWEH-70, wspólnie dotychczas stosowanych z nadtlenkiem benzoilu (NB) i wodoronadtlenkiem kumenu (WNK) — na przebieg procesu polimeryzacji styrenu w drewnie przy zastosowaniu dwóch parametrów obróbki termicznej i dwóch okresów trwania tej obróbki.

Przeprowadzone badania wykazały, że lignomer wytworzony przy użyciu NWEH-70 charakteryzował się lepszymi właściwościami niż w przypadku zastosowania ABVN. Zastosowanie w składzie substancji inicjujących NWEH-70 wyraźnie skraca proces polimeryzacji styrenu w drewnie. Obecność w styrenie ABVN powodowała częściowe wydalenie styrenu z drewna, szczególnie w przypadku stosowania na początku obróbki termicznej cieczy o wyższej temperaturze.

#### ВЛИЯНИЕ СОРТА НИСКОТЕМПЕРАТУРНОГО ИНИЦИАТОРА ПОЛИМЕРИЗАЦИИ НА ХОД ПРОЦЕССА ПОЛИМЕРИЗАЦИИ СТИРОЛА В ДРЕВЕСИНЕ И НЕКОТОРЫЕ СВОЙСТВА ЛИГНОМЕРА

##### Резюме

На ход процесса полимеризации влияет, кроме условий термической обработки, также подбор сорта и количества инициаторов. Целью исследований было определение влияния двух низкотемпературных инициаторов ABVN и NWEH-70 вместе с применяемыми до сих

пор перекисью бензоила (NB) и гидроперекисью кумола (WNK) на ход процесса полимеризации стирола в древесине с применением двух режимов термической обработки.

Исследования доказали, что лигномер произведенный с применением NWEH-70 характеризуется лучшими свойствами чем в случае применения ABVN. Применение инициатора NWEH-70 значительно сокращает время полимеризации. Другой инициатор — ABVN вызывает частичное удаление стирола из древесины, особенно в случае применения высшей температуры в начале термической обработки.

Adres autora:

Prof. dr hab. Maciej Ławniczak  
Akademia Rolnicza w Poznaniu  
Katedra Mechanicznej Technologii DREWNA  
ul. Wojska Polskiego 38/42, 60-637 Poznań