

## Scientific report of STSM

Name: **Quantitative Neutron Imaging (QNI) Software Learning and Neutron Imaging Data Analysis**

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For the successful consolidation of aged wood the consolidant (polymer) solution has to penetrate into the sufficient depth of the material. Its penetration depends on wood permeability and an impregnation method as well as the properties of the polymer and its solution. For that reason it is necessary to use methods which give information about the flow of consolidant solution and its distribution through the wood, because it could help with adjustments of consolidation technology. Neutron radiography is such a method which makes possible to study dynamic processes, i.e. to observe the flow of liquids through the wood in real time and determination of the resin amount in a non-invasive way.

The acrylate solutions penetration was observed through the wood by neutron radiography. Conditions and the technological procedure of the measurement were adjusted to get the best results. The evaluated data indicate velocity variations of the studied solutions depending on the type of acrylate, their concentration and the used solvent. In first order, the exponential attenuation law is valid. But the quantification of acrylic solution in wood samples which was done previously is not absolutely correct, because when evaluating the data the scattering artifacts (multiple scattering) of neutron radiation in wood was neglected. The amount of a specific material (like polymer) can be determined by the transmission measurement (image of the sample) if the attenuation process is well described. Then it can be inverted and the material amount can be derived. If the scattering in the sample is high (in particular when the water or polymer amount is high), then in this case this law is not exactly valid. There are some effects distributing this law or superposed to it.

Recently, Paul Scherrer Institut has developed software (QNI 1.0) providing correction for neutron radiation scattering by wooden samples and other hydrogenous materials, based on scattering simulations with the particle Monte-Carlo transporting code MCNP. The QNI software eliminates deviations from the first exponential law and allows obtaining exact results which can be used for the

better interpretation of polymer solution behaviour during its flow through the wood. The aim of the STSM was to learn the QNI on site at PSI and to use the acquired knowledge for measured data processing (amount of the measured data is 18.7 GB).

I got acquainted with QNI software and learned how to operate it during the stay at PSI. Now I am able to use it independently for data processing. The QNI software tool was hand over by the PSI colleagues free of charge.

The software does not allow processing my measured data in series for the moment. It is necessary to process individual data items one by one which is quite time consuming. For that reason only selected data items from each data set have to be processed. The transmission data have to be evaluated in the next step by image processing software and consequently by Microsoft Excel or similar software.

The first step of the data evaluation is their “normalisation” by QNI software. The result of this data processing is information about a sample transmission. The transmission data have to be evaluated in the second step by image processing software (ImageJ). The result of the processing is an image data set, which visualises liquid movement. These images are obtained by division of impregnated samples by non-impregnated ones (without liquid). In this way, the wooden structure is eliminated and the resin and solvent is obtained alone. Figure 1 shows a visualization image illustrating the xylene movement. Figure 2 shows the visualization inverted into the false color. Figure 1 and 2 only illustrate experimental set, velocity of the liquid uptake and its distribution in the samples.

Fig.1 – Xylene penetration into lime wood in axial direction. Height of the samples is 6 cm.

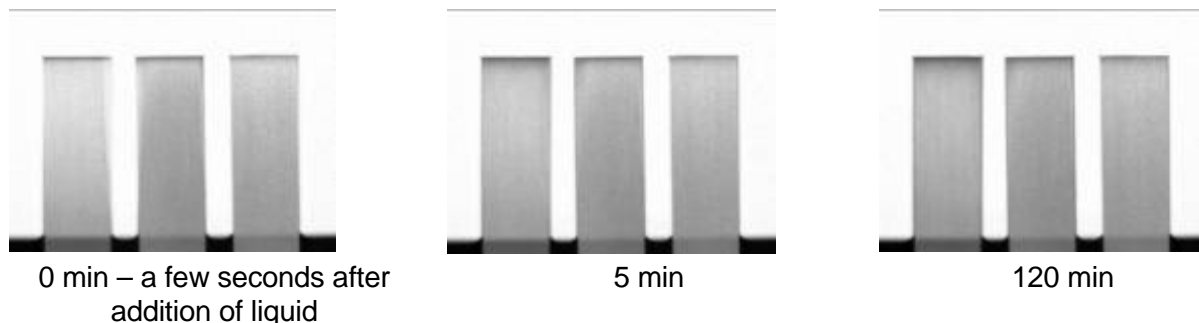
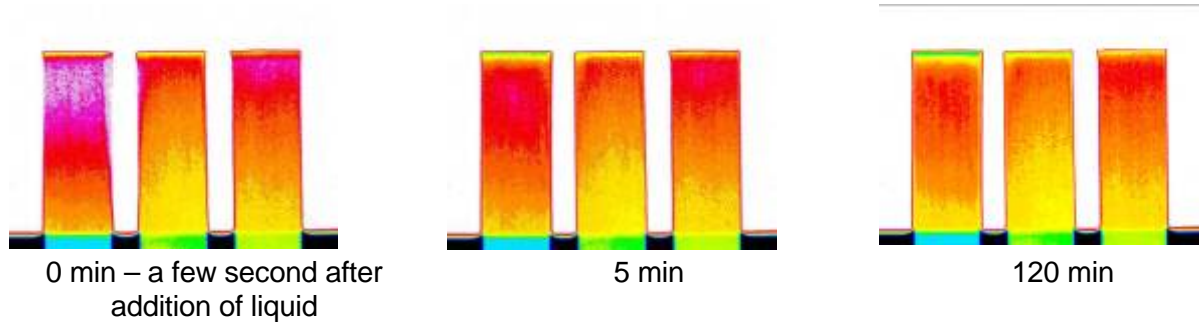


Fig.2 - Xylene penetration into lime wood in axial direction, inverted into false color.



The third step of the data processing is an extraction of transmission values from the image by image software tools. The obtained table of extracted values corresponds to a planar numerical expression (tangential x axial direction) of sample transmission in the defined time and it is averaged in the tangential direction of the sample to get one-dimensional illustration of the sample transmission. Then one-dimensional data are processed in Microsoft Excel – figure 3. Figure 3 shows comparison of the evaluated data which were processed in first step by QNI and which were not processed by the software. It is clearly visible that results processed by QNI have got higher transmission values which correspond to amount of the liquid in the wood (1 – no transmission of the neutrons. 0 – no neutrons pass through the sample).

The figure 3 illustrates well the liquid front travel through the wood as well as the increasing amount of the liquid. The x-axis basically corresponds to position in the sample (the sample height), the sample foot lying in the point of intersection of the x and y axes (the liquid travels from left to right). The bottom part of the sample exhibits quite high transmission (x-axis value 0-60), which decreases in axial direction of the sample. The transmission values rapidly increase around position 510. This phenomenon corresponds to xylene accumulation beneath the upper surface of the transverse section through the sample.

The examples of the data evaluation given in the figure 3 show that the data processing by QNI allows best possible interpretation during their consecutive processing. All measured data sets are going to be processed successively in the following weeks.

Figure 3 – Comparison of the data evaluation processed (1min qni and 120min qni) and unprocessed by QNI (1min and 120min) – Xylene uptake by lime in axial direction 1 and 120 min from the solvent dosing. Position in x axis corresponds to height of the sample and T is transmission value.

