Determination of the Size Coat

Abstract
The determination of the size coat will be described as it has been done so far. According to the laboratory determination of size coat by desizing (by cooking) and the quantum method (by drying), some differences have been identified. By desizing the size coat showed a higher percentage, so that it can be ascertained that by cooking, in addition to the size, a part of fibres and dirt was removed from the yarn, leading to a fault in determining the size coat. The analysis proved that the quantum method for determining the size coat, as the most accurate, is the most approximate to the continuous measurement based on the substance’s content.

Key words: size coat, size box, continuous measurement, outlet moisture, inlet moisture, concentration.

Introduction
The number of warp thread breaks on the loom depends to a great extent on the percentage and quality of the size coat, and if this changes during the sizing process, the number of thread breaks will change, as will the production of the looms as well as the quality of the end product. Keeping the size coat constant is not simple, and it depends on a series of factors associated with raw materials, size and automation of the sizing machine, etc. Experts and researchers have been dealing with sizing problems ever since the first application of sizing. One of the basic tasks is to determine size coat as fast and accurately as possible, and to keep it constant during the sizing process [10,12].

One of the basic prerequisites for obtaining good and economical sizing is that size coat in the warp is uniform while sizing one batch. To achieve this, it is necessary to keep some influencing factors constant such as concentration, viscosity, the temperature of the size in the size box, the speed of the warp through the size box, the inlet moisture of the warp before sizing, the outlet moisture of the warp after sizing, the squeezing force, the tension of the warp threads in the size box, etc.

To optimise the size coat qualitatively and quantitatively, it is necessary to include the following parameters: the raw material of the yarn and its characteristics such as yarn count, yarn twist, fibre length, type of spinning, type of the loom, article, season, and climatic conditions for processing natural fibres, etc.

Methods of Optimising and Maintaining the Size Coat on the Warp

1. Desizing was one of the first methods for determining the size coat, and it produces relatively accurate results. The procedure is simple and carried out by rinsing and drying the samples. The disadvantage of this method is that it is carried out at the laboratory after sizing, and the amount of the size coat on the warp at the moment of sizing is unknown, so it is impossible to affect the possible change of the size coat during sizing. By this method the yarn is cooked for some time in a defined bath. The disadvantage is that a part of the fibres and other additions is removed, so that a higher value of size coat is determined than the real one; as it is calculated by equation (1).

\[
S_{1,1} = \frac{G_{dr} - G_{ds}}{G_{dr}} \times 100 \quad (1)
\]

where:
- \(S_{1,1}\) - size coat in percent obtained by desizing (using chloride acid, soft water or distilled water);
- \(G_{dr}\) - mass of dry sized yarn, in g;
- \(G_{ds}\) - mass of dry desized yarn obtained after cooking and rinsing, in g.

2. Drying unsized samples (before immersing warp into the size) and sized warp samples at the exit of the size box (both of the same length). They are completely dried and weighed, and the difference of their weight is used to calculate the size coat by equation (2).

\[
S_{2} = \frac{G_{ds} - G_{d}}{G_{d}} \times 100 \quad (2)
\]

where:
- \(S_{2}\) - size coat obtained by drying the samples, %;
- \(G_{ds}\) - mass of the dry sized yarn, in g;
- \(G_{d}\) - mass of the dry unsized yarn, in g.

Using infrared devices for the drying samples, the results can be obtained within 10 to 15 minutes [14]. This method is considered as one of the most accurate methods, especially if the examination is performed on the same yarn sample before and after sizing, which is difficult to effectuate.

3. By taking a wet sized warp sample from the sizing machine just before...
measuring warp moisture by means of 
b-irradiation absorption (FH 46 device 
developed by Frieske & Hoepfner GmbH), 
infra-red IR reflection (HMF-IRP device 
manufactured by Mahlo GmbH + Co. KG), 
and microwave absorption (AF 310 device 
fabricated by Pleva GmbH). By this method 
the size coat can be controlled during sizing, 
and can be kept constant by changing the 
force on the last pair of the squeezing 
rollers. When measuring warp mois- 
ture, it is necessary to carry out the cali- 
bration according to the raw material 
composition of the warp, density, yarn 
count, size agents and other parameters 
affecting measuring signals [1-3,13].

The $\beta$-radiation absorption 
(radionuclidic) method
This was the first method of this kind. 
Contact-free measurement of the spe- 
cific warp mass at the entry of the size 
box and at the exit of the dryer with 
their difference is regarded as the size 
coat keeping outlet moisture constant. 
The device function by using the 
absorption of $\beta$-radiation of radioactive 
isotopes, e.g. $^{85}$Kr for measuring 
range 50-1000 g/m$^2$ (±1 g/m$^2$) or at 
$^{90}$Sr for the range of 250-2500 g/m$^2$ (±1 
g/m$^2$). The measuring range of the 
mass of 10-50000 g/m$^2$ can be achieved 
by this method. This method has not 
been accepted because of its high cost 
and its sensitivity during production 
conditions [15,16].

Infrared reflection (IR) method
The IR-device for measuring moisture 
functions by using two different wave- 
lengths; one sensitive to moisture 
changes, and the other having almost 
no sensitivity to warp moisture, or 
with a minimal reaction. The intensity 
of reflection with a specific wavelength 
of monochromic light depends on the 
content of water in the warp, e.g. the 
wavelengths 1450 nm and 1930 nm 
produce a very high sensitivity by 
changing moisture in the infra-red 
range [6]. A small difference in the 
intensity of reflection with a different 
water portion, e.g. in the warp, will lie 
in the range of wave lengths 1200-1300 
nm and in the range 1700 nm - 1850 
nm, especially by using older measur- 
ing instruments that are not sufficient- 
ly sensitive to signals. The devices for 
measuring moisture by this method 
are mentioned above, the HMF-IG-P 
and IR-camera [4]. When measuring 
warp moisture at the exit of the size 
box by IR-reflection, the size coat can 
be calculated by equation (4) [16].

$$S_1 = \frac{W_{63}}{K} \frac{K}{100 - K}$$

$S_1$ - size coat, %;  
$W_{63}$ - outlet moisture of the warp, %;  
$K$ - concentration of the size, %.

**Experimental**

In order to obtain sized samples of 
yarn of different counts under differ- 
ent sizing conditions, a laboratory-siz- 
ing machine was constructed. This is a 
unit that completely simulates the 
process-sizing machine, which is 
equipped with devices for continuous 
measuring inlet moisture, entry ten- 
sion and outlet moisture. The results 
were collected in the computer for 
future processing. The size concentra- 
tion was determined in the refrac- 
tometer by taking samples.
Entry warp tension was measured by a tensiometer (Smidt Co.) earlier used manually for the same purpose. It was necessary to save these signals, which were transmitted via the amplifier into the computer, for continuous measuring and data saving. Exit warp moisture was measured by a contact-free device with monochromatic IR radiation, based on previous measurements. The measuring device was constructed at the Electro-Technical Faculty of Osijek in co-operation with the Ruđer Bošković Institute of Zagreb. The yarn samples were sized by size agents based on PVA (polyvinylalcohol) and CMC (carboxylmethylcellulose) applied in the ratio 1:1. The size coat was determined by taking samples of the sized yarn or by continuous measurement of agent parameters, and then calculated by appropriate equations.

The size coat was determined by the methods described below, the first two according to the ASTM-D334-GOT and DIN-54285 standards.

1) A sample of sized yarn, mass 5 g, was dried completely and weighed. A 400 ml glass cup was filled with 200 ml of 0.1 mol HCl, and was heated up to boiling point. Then the sample was immersed, the cup was covered by heat-resistant glass, and was kept boiling for the next 30 minutes. During this period, the size was degraded by acid. The cup content was then poured on the sieve against the yarn and sieve, the sample was scattered and put into a drying pot. After drying to absolute dryness, the sample was weighed and the size coat was calculated according to the equation (1).

2) A sample of sized yarn, mass 5 g, was dried up and weighed. A 400 ml glass cup was filled with 200 ml of soft water and was heated up to boiling point. The sample was immersed in hot water; the cup was covered with heat-resistant glass, and was kept boiling for 30 minutes with periodical mixing. Afterwards the sample water was poured on the silk sieve and was washed out with 100 ml of hot soft water, then by turns with hot and cold water 100 ml each. After longer squeezing, by pressing the glass short stick against the yarn and sieve, the sample was scattered and put into a drying pot. After drying to absolute dryness, the sample was weighed and the size coat was calculated according to the equation (1).

3) This method of determining size coat was carried out identically with the previous one No. 2, only that distilled water was used instead of soft water.

4) The method of determining size coat by drying the sized and unsized yarn samples of the same length, and afterwards by weighing. The length was obtained by hanging the yarn with a pre-load of 0.5 cN/tex on a 0.5 m segment. The size coat was determined by the equation (2).

As the wet yarn in the size box, under tension, has lower resistance to elongation resulting from yarn elasticity, its length was tested before and after sizing, but no difference was shown. The length of the yarn from the unwinding end to the winding end on the laboratory-sizing machine was relatively short, and there were no signs of stretching. The tests were carried out on three kinds of yarn and with three entry tensions. For this reason it was supposed in this case that the yarn length remained the same as well as the yarn count. The size coat was taken as a difference in the mass before and after sizing, which cannot be maintained with the above-mentioned methods. When determining the size coat on the yarn by cooking or degrading chemical agents, other additions on the yarn are removed, such as short fibres, impurities, wax, etc.; this part is taken afterwards as size coat, which represents a fault in determining the size coat. Furthermore, as this method is not completely accurate because of some possible variations in yarn unevenness, possible stretching (elongation) of the yarn during sizing, the fifth method was pursued.

5. The procedure with a larger amount of size and samples was repeated, in order to be able to maintain with certainty that the size coat obtained by the quantum method (by drying samples before and after sizing) is the closest to the size coat obtained by means of measurement values inserted in equation (1).

One hundred samples of the same yarn were taken at 100 m each, wound on skeins and dried up to absolute dry mass. Each sample had its own mark. After drying the yarn was cooled off in an excitor, and each sample was weighed. The yarn dwelt in a climatic environment for three days, and was then wound on a crosswound bobbin, so that each bobbin contained 4 skeins or samples. Between each sample (5 m) of other yarn was wound, so that at
Table 1. Size coat S obtained by different methods.

<table>
<thead>
<tr>
<th>Sample</th>
<th>$S_{1,1}$, %</th>
<th>$S_{1,2}$, %</th>
<th>$S_{1,3}$, %</th>
<th>$S_{2}$, %</th>
<th>$S_{3}$, %</th>
<th>$S_{4}$, %</th>
<th>$W_{ki}$, %</th>
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<tr>
<td>1</td>
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<td>7.45</td>
<td>7.41</td>
<td>7.18</td>
<td>7.24</td>
<td>7.15</td>
<td>6.8</td>
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<td>6.77</td>
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<td>6.23</td>
<td>6.83</td>
<td>6.30</td>
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<tr>
<td>3</td>
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<tr>
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<td>6.02</td>
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<td>6.22</td>
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<tr>
<td>5</td>
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<td>5.59</td>
<td>5.55</td>
<td>5.12</td>
<td>5.45</td>
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<tr>
<td>6</td>
<td>6.96</td>
<td>6.34</td>
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<td>5.83</td>
<td>6.25</td>
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<td>3.77</td>
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<tr>
<td>19</td>
<td>3.34</td>
<td>3.01</td>
<td>3.01</td>
<td>2.85</td>
<td>3.19</td>
<td>3.14</td>
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</tr>
<tr>
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<td>4.23</td>
<td>3.44</td>
<td>3.23</td>
<td>2.88</td>
<td>3.33</td>
<td>2.71</td>
<td></td>
</tr>
</tbody>
</table>

$S_{1,2}$ - (Table 1, Figure 2): size coat obtained by desizing with HCl (%),
$S_{1,3}$ - size coat obtained by desizing with soft water (%),
$S_{2}$ - size coat obtained by drying up to absolute dryness of the yarn sample before and after sizing - quantum method (%),
$S_{3}$ - size coat obtained by the basic content of the substance (%),
$S_{4}$ - size coat obtained by the equation from the literature (%),
$W_{ki}$ - yarn moisture at the entry of the size box (%).

Table 2. Experimental and arithmetic values when determining the size coat - investigation performed on the same sample before and after sizing the yarn.

<table>
<thead>
<tr>
<th>Yarn measurement values</th>
<th>K, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total mass of absolute dry unsized samples (g)</td>
<td>140.5595</td>
</tr>
<tr>
<td>Total mass of absolute dry sized samples (g)</td>
<td>149.614</td>
</tr>
<tr>
<td>$S_2$ (%)</td>
<td>6.44</td>
</tr>
<tr>
<td>$W_{ki}$ (%)</td>
<td>6.18</td>
</tr>
<tr>
<td>$W_{ki}$ (%)</td>
<td>64.48</td>
</tr>
<tr>
<td>$S_4$ (%)</td>
<td>6.446</td>
</tr>
</tbody>
</table>

Figure 2. Diagram of the size coat obtained by different methods: S - size coat (%), N - number of measurements, 1 - curve of the size coat obtained by desizing with HCl, 2 - part of the size coat according to the literature at increasing entry yarn moisture.

Sizing all 100 m of yarn could be sized under the provided conditions and without stopping every 100 m. At machine stoppage after 100 m of the first sized sample (25 ends, 100 m each), some yarn was found in the size box used for binding the samples. The yarn was sized with 4 size concentrations, whilst all other conditions were constant during sizing. During sizing, the inlet moisture, entry tension, concentration and outlet moisture were measured. The measuring signals were saved in a computer for further processing. After sizing, the yarn was properly separated from the auxiliary yarn, wound on skeins, and 4 samples of the sized yarn with 25 ends each were obtained. The yarn was dried up to the absolute dry sample, cooled off in the exicator and weighed. According to the marks on the samples (before sizing), the mass of the samples (that were sized at the same time) was summed, and the yarn mass was obtained for one condition (one concentration) before sizing. The mass was weighed after sizing, and by using equation (2) the size coat was summed ($S_2$,%). The size coat ($S_2$,% based on equation (6) was obtained from the average values of the measurement magnitudes ($W_{ki}$,%, $W_{ki}$,%, and K%). The obtained values of this examination are summarised in Table 2 and Figures 3 and 4. The size coats obtained by drying ($S_2$%) according to equation (2) and the size coat ($S_2$%) obtained by equation (6) have a high correlation.

Results

The size coat obtained by different methods gave different results (Tables 1, 2 and Figures 2-4). Removing the size by desizing according to equation (1) gave the highest values of size coat, especially with HCl. Since the size agents are based on synthetic sizes, meaning that they can be removed by water, the tests were carried out by desizing with soft and distilled water. The size coat obtained by soft and distilled water with each sample is similar, and there are no major differences. If the values obtained by desizing with water and HCl are compared, the difference is apparent with almost all samples, and the height of the size coat is higher with HCl. A more intense removal of the size, fibres and impurities was more apparent at desizing with HCl. For this reason other methods of determining the size coat were applied.

The size coat was determined according to the size coat obtained by drying the samples of yarn (quantum...
method) before and after sizing up to the absolute dry samples and according to equation (2). This method proved that the size coat is actually the difference between the mass of the yarn before and after sizing, and there is no possibility of any fault occurring while desizing and removing other additions from the yarn, with the exception of size. Thus, this method is supposed to be more accurate. The size coat in all the samples obtained by the quantum method has a lower height than that obtained by desizing.

Since this method also has its own disadvantages, such as shrinking and stretching during wet processing and yarn unevenness, a test of size coat was performed on the same samples by the quantum method. By this method possible faults of shrinking and stretching and yarn unevenness could be avoided. The obtained results had certain variations from the previous quantum method when the same yarn was tested, but different samples of the yarn. Determining the size coat on the same samples led to the most accurate evaluation of the size coat.

Since the size coat is continuously measured and regulated on modern sizing plants, it is very important to find the most accurate method for determining the size coat. According to the latest investigations and auxiliary instruments offered on the market for the continuous maintenance of the size coat, the size coat is determined and regulated automatically according to equation (4). Since this equation does not completely include the substance content (or all of the influencing parameters), a new analysis was chosen resulting in equation (5). The accuracy in determining the size coat by continuous measurement of the parameters according to equation (5) confirms that these values are very close to the values in the quantum method of the same samples (Figure 2), and they give a very high correlation of the values (Figure 3).

### Conclusions

Size coat is one of the most important parameters in the function of the number of warp yarn breaks in weaving. In order to follow and maintain the size coat constant during sizing, it is necessary to control the parameters affecting the changes of its value. The determination of the size coat on a sized yarn sample is performed in several ways, and they are used according to specific standards. Since synthetic size agents are used mostly nowadays, and are removed by water, the quantum method is supposed to be more accurate than the desizing method. In desizing the yarn by cooking in HCl, the size coat was higher than that obtained by the quantum method. In desizing by cooking some of the fibres and other additions were removed, together with the size.

By continuously determining the size coat it is possible with the aid of substance content to determine the most influential parameters, and by their control and regulation it is possible to maintain size coat. The size coat obtained by substance content is closest to that obtained by the quantum method carried out at the laboratory. This confirms the accuracy of the equation for substance content considering the three influencing parameters: inlet moisture, concentration and outlet moisture. The obtained values of the size coat have a very high correlation.

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