INFLUENCE OF MASS DISTRIBUTION ON ELECTRIC BREAKDOWN STRENGTH OF INSULATING PRESSBOARD

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1 INTRODUCTION

Paper and Pressboard made out of pure virgin unbleached kraft pulp has an outstanding importance for liquid immersed high voltage operating equipment like power transformers since the beginning of the 20th century till now [1, 2]. In a high voltage power transformer cellulosic pressboard is applied in a variety of different components, such as stripes, spacers, disks, cylinders and moulded parts. Depending on the specific function of these components in the complex assembly of a power transformer various material properties have to be provided to fulfil the design requirements for assembling, testing and decades of safe and reliable operation. Among other important properties the electric breakdown strength of pressboard barriers plays an important role for operation reliability of a power transformer.

More profound knowledge of the basic functioning and the influencing factors of material properties of high grammage insulating pressboard should offer new options for improvements in designing and manufacturing insulation components and eventually as well in the overall performance of power transformers [1, 2].

Against this background the purpose of this investigation was to evaluate the suitability of different manufacturing processes of high grammage pressboard in terms of electric insulation properties by determining the influence of fibre uniformity on electric breakdown strength.

2 EXPERIMENTS

2.1 Sample preparation

Pressboard samples with different grades of fibre uniformity were prepared using a Rapid-Köthen handsheet former. After forming, the sheets of wet board were pressed and dried using a laboratory hot press. The converting conditions chosen led to an average thickness of 1.05 mm ± 0.05 mm and an average apparent density of 0.93 g/cm³ ± 0.04 g/cm³. Pure unbleached kraft pulp with a freeness of 27 Schopper-Riegler numbers was used as raw material for all samples. These are typical characteristics of a low density pressboard. To conduct further processing square specimens of 100 mm x 100 mm were taken out of the middle of the handsheets and their basic properties were measured according to ISO 187 and ISO 534 respectively. For each board grade a set of 16 single samples was produced and examined as follows.

2.2 Evaluation of mass distribution

Mass distribution of the pressboard samples was measured using X-ray adsorption of the sample material. The measuring system consisted of an X-ray tube and a corresponding sensor to detect transmission of X-ray through the sample at discrete positions. Mass distribution data was collected and recorded over the entire surface of the sample automatically by moving the sample between the X-ray source and the transmission detector with the help of an automated XY-table. Thus the mass distribution could be examined in a quick and accurate way. After filtering, the obtained values have been converted to a resolution of 0.25 mm x 0.25 mm to get round numbers for interpretation. These values further on are named as “discrete measured values”.

2.3 Electric breakdown strength

The short-time breakdown strength (AC) according to IEC 60243-1 was measured on the vacuum dried and mineral oil (Nynas Nytro 4000x) impregnated samples to evaluate the electric strength of the produced samples. The test setup was equipped with unequal electrodes with diameters of 75 mm and 25 mm respectively. The samples were positioned centrically between the electrodes. Figure 1 show the test setup according to IEC 60243-1.

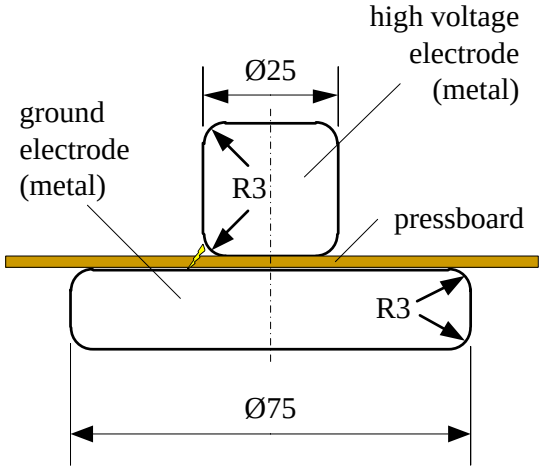

Figure 1. Used test setup for determination of electric break down strength [3]

Breakdown strength and water content of the mineral oil used were measured before and after the trials to make sure that the test conditions complied with the standard.

3 RESULTS

3.1 Mass distribution

The radiometric analysis provides a qualitative impression of the fibre uniformity of high grammage boards, similar to an optical inspection of a thin paper via light transmitting, as well as the corresponding data for a statistical evaluation.

Figure 2 shows representative examples of the 2D-charts obtained for the 5 different board grades produced. The colour code for deviation around the mean value of grammage of the individual samples in figure 2 has been chosen identical for all grades.

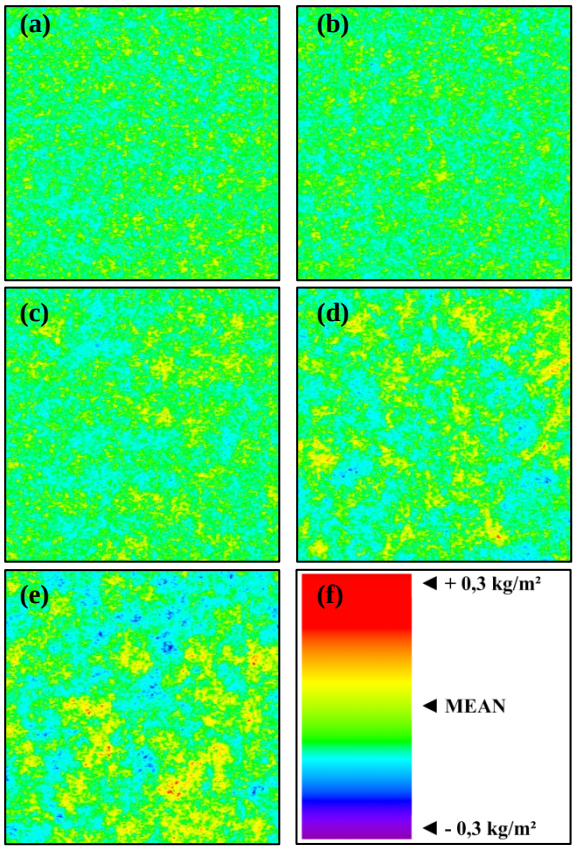

Figure 2 (a–f). 2D-Visualisation of fibre uniformity of pressboard grades (a)–(e) over the entire samples area of 100 mm x 100 mm. The used colour code for all samples is shown in chart (f).

Hence, the uniformity of the different board grades can directly be compared.

For a statistical evaluation of the different board grades the relative standard deviation (RSD) of fibre mass distribution of the samples was examined as well. Figure 3 shows the RSD of grammage distribution, in which different integration areas were chosen. The error indicators in figure 3 show the range of the RSD values determined for each test series with 16 individual samples.

As it could be expected, figure 3 shows that the RSD of mass distribution decreases with increasing integration area. What can also be observed is that the gradient of change of RSD of mass distribution over the different board grades depends on the integration area considered, if the same total area of the entire samples is examined.

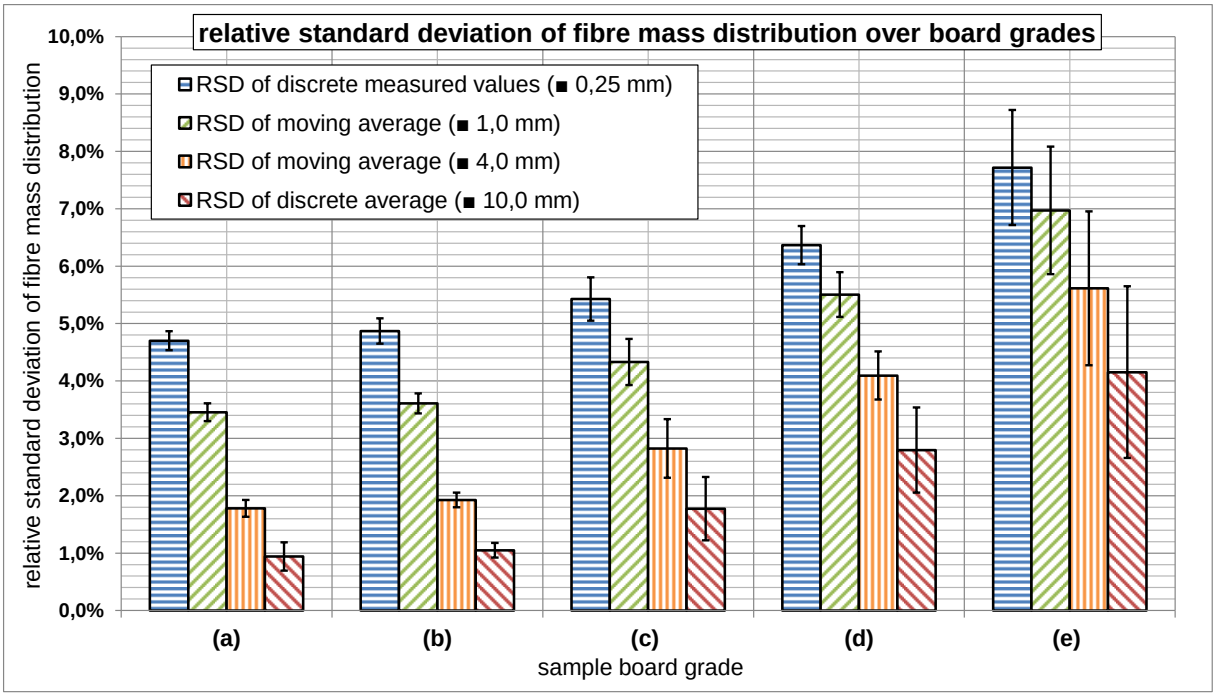

Figure 3. Relative standard deviation of fibre mass distribution (grammage) of pressboard grades (a)–(e). The ■ values in the legend give the square edge length of the considered integration area.

Whereas the relative change from grade a to grade e is about 60 % (4.7 % to 7.7 %) when considering the RSD of the discrete measured values, the same relative change can be evaluated with 340 % (0.9 % to 4.2 %) when the RSD of discrete squares of an edge length of 10.0 mm is considered. The comparison of these two evaluations has to be seen under the fact that the different values are representing the same specificity of fibre uniformity in the samples, as visualised in figure 2. The intention of the preceding approach was to figure out, which of the evaluation criteria was the most appropriate one for characterizing the influence on the properties of the pressboard, such as electric or mechanical strength.

3.2 Electric breakdown strength

The test results for the electric breakdown strength are given in figure 4. Unexpectedly no significant difference between the different pressboard grades could be observed in the tests made. Although a considerable number of individual samples had been examined for each grade, the deviation between test results gave no indication for any influence of fibre uniformity on the electric strength values measured.

4 Conclusion

It is well known from a lot of references, from deduced coherent theories and also stated in international standards derived from those, that the average apparent density and the nominal thickness are the main influencing parameters for the achievable electric strength of insulating pressboard made out of pure unbleached kraft pulp [4, 5].

Due to the fact, that the local thickness of the prepared boards varied far less than the fiber mass distribution, the specific distribution in fiber mass within the selective produced samples led to a corresponding local distribution of apparent density. Hence, a reduction in electric strength with decreasing uniformity of the local apparent density could be expected.

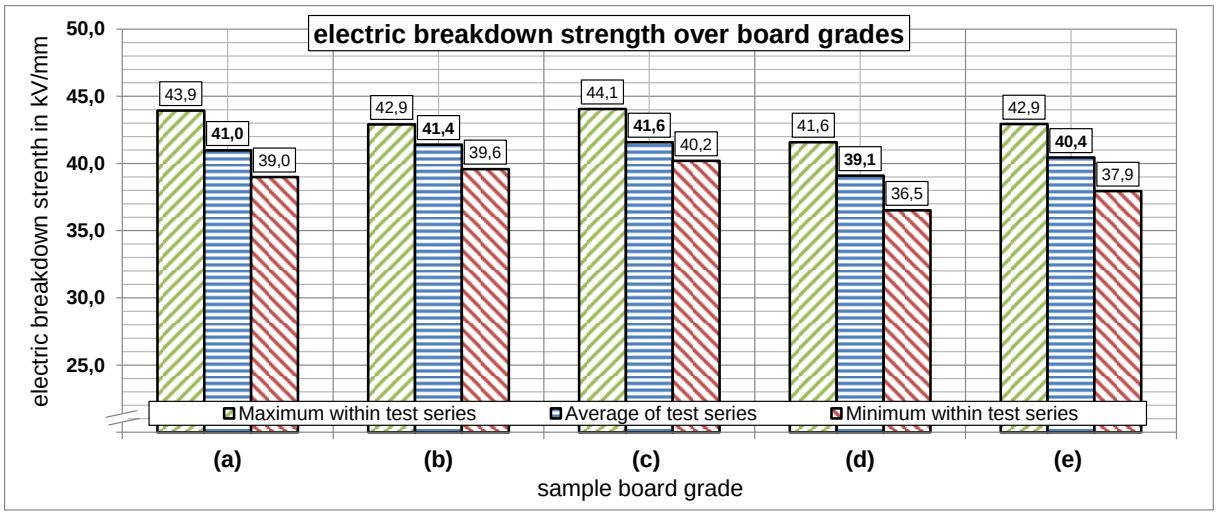

Figure 4. Average and value range of test results for electric breakdown strength (AC) of pressboard grades (a)–(e) (16 single tests for each grade)

The fact that no such influence was observed, suggests that the uniformity in local fiber mass distribution, respectively in local apparent density distribution, has no significant influence on electric breakdown strength within the examined range of material parameters of insulating pressboard. However, it should be taken into account that – at the moment – the results reported in this paper are restricted to pressboards with a thickness of about 1,0 mm and average apparent densities below 1,0 g/cm³.

5 Summary

The paper describes a non-destructive method for analyzing and evaluating the homogeneity of pressboard with grammages of 0.2 kg/m² and above, which could not be analyzed by common light transmitting methods. Examining board samples with different grades of uniformity of fiber mass distribution and their electric strength after mineral oil impregnation with the help of this method allows scientists and engineers a better understanding of the interdependencies of material properties of cellulosic pressboard and their inner structure. The results can also be used to better interpret electric breakdown phenomena in two-phase electric insulating systems, especially for liquid immersed cellulosic insulation systems.

Keywords: insulating pressboard, oil immersed solid insulation, electric breakdown strength, cellulose, formation, mass distribution

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