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INVESTIGATION OF JOINTS FOR FUNCTIONAL OPV-FOILS ON TEXTILES

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ABSTRACT: Organic photovoltaic (OPV) can be used for power and light generation. Additionally OPV can be produced as thin plastic foils and be joined with textiles for many applications. The aim of this research study was finding an optimal joining process of foils on textiles. Therefore different joining methods were analysed with focus on the strength of the joining. The analysis of the results indicates that sewing with a long stitch length results in the highest strength. The stitch length is the most important factor for the seam strength. The adhesive bonding has a much lower strength than the sewing joints.

Key words: OPV, joining, plastic foil, sewing, adhesive bonding

TEKSTİLDE FONKSİYONEL OPV-FOLYOLARININ BİRLEŞTİRME İŞLEMİNİN İNCELENMESİ

ÖZET: Organik fotovoltaik (OPV), güç ve ışık üretimi için kullanılabilir. Ayrıca OPV ince plastik folyo olarak üretilebilir ve birçok uygulamalarda tekstil ile birleştirilebilir. Bu araştırmanın amacı, tekstilde optimum folyo birleştirme prosesinin bulunmasıdır. Bu nedenle birleştirme işleminde, mukavemete odaklanarak farklı birleştirme metodları analiz edildi. Analiz sonuçları, en uzun ilmek uzunluğuna sahip dikişlerin en yüksek mukavemete sahip olduğunu göstermiştir. Dikiş mukavemeti için en önemli faktör ilmek uzunluğudur. Yapıştırma birleştirmesinin mukavemeti, dikiş birleştirmesine göre daha düşüktür.

Anahtar kelimeler: OPV, katılma, plastik folyo, dikiş, yapıştırma

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1. INTRODUCTION

In the future organic photovoltaic (OPV) and organic light emitting diodes (OLED) can be used for power and light generation. Both OPV and OLED can be produced as thin plastic foils and in addition can be joined with textiles for many applications due to their limp behaviour, flexibility and drape. Figure 1 displays the layers of OPV- foils schematically. [1, 2]

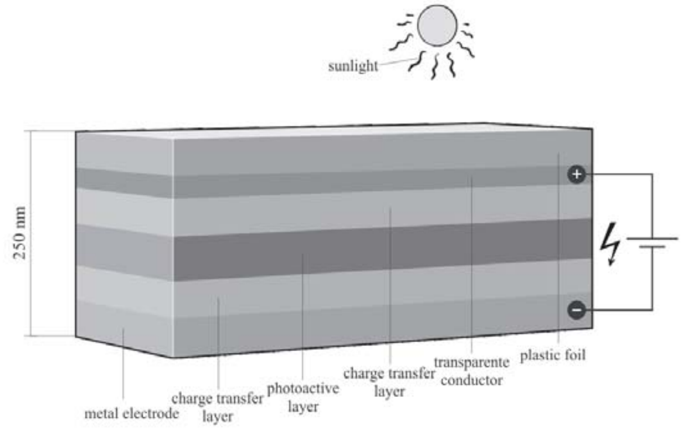

Figure 1. Schematic display of an OPV- foil function

In a study at the Institut für Textiltechnik (ITA) at RWTH Aachen University the optimal way of joining these foils with textiles was investigated. The aim of this research study was to define parameters for the optimal joining of plastic foils with textile that can be used as base for an industrial production. Different joining methods (e.g. sewing or adhesive bonding) were analysed with the focus on the strength of the joint. The joint was characterized using interlaminar energy release rate G as an indicator for its stability.

2. MATERIAL AND METHOD

For the methodical analysis of the sewing and bonding joints design of experiments was chosen. Pre-tests showed the influence of the following four factors on the joint strength for the sewed samples:

- work piece
- sewing thread
- stitch length l_{stitch}
- needle size

These influencing factors regarding the sewed samples were varied and compared with each other.

Two woven fabrics made of cotton spun yarn were used – named twill and jeans in this paper. The twill has got a warp density of 38/cm and a weft density of 23/cm. The used jeans material features a warp density of 25/cm and a weft density of 18/cm. The two sewing threads were made out of 100 % Polyester, one with a yarn count of 216 dtex and the other one with a yarn count of 750 dtex. For the stitch length l_{stitch} 2 mm and 4 mm were chosen. The needle size was varied with 60 Nm and 90 Nm. The double locked stitch was used for all samples, because it is the most used stitch type for the production of fabrics. All sample specifications of the sewing samples are given in Table 1.

Table 1. Factorial design for the sewing samples

Sample ID	work piece	sewing thread	stitch length	needle size	sample quantity
A	Twill	216 dtex	2 mm	90 Nm	5
A*	Twill	216 dtex	2 mm	60 Nm	5
B	Jeans	216 dtex	2 mm	90 Nm	5
C	Twill	750 dtex	2 mm	90 Nm	5
D	Jeans	750 dtex	2 mm	90 Nm	5
E	Twill	216 dtex	4 mm	90 Nm	5
E*	Twill	216 dtex	4 mm	60 Nm	5
F	Jeans	216 dtex	4 mm	90 Nm	5
G	Twill	750 dtex	4 mm	90 Nm	5
H	Jeans	750 dtex	4 mm	90 Nm	5

For the adhesive bonding two different materials were used for the experiments. On the one hand a spray adhesive was used which was applied to the fabric by spraying. On the other hand a 2-component epoxy-adhesive was used for the experiments. The two components were manually mixed and applied onto the fabric. All sample specifications of the adhesive bonding samples are given in Table 2.

Table 2. Factorial design for the adhesive samples

Sample ID	work piece	adhesive	sample quantity
I	Twill	2-component epoxy -adhesive	5
J	Jeans	2-component epoxy -adhesive	5
K	Twill	spray adhesive	5
L	Jeans	spray adhesive	5

The same foil was used during the whole sample production. The basic material for the OPV or OLED- foil is Polyethylenterephthalat (PET), a thermoplastic polymer. The foil is 0,1 mm thick.

To compare sewed seams with adhesive bondings and to evaluate the joint strength, the interlaminar energy release rate G was measured. This factor was chosen, because it indicates the joint strength of laminar joints. The interlaminar energy release rate G describes the area below the stress-strain curve and indicates the seam strength. The test is described by DIN EN 6033. Usually, this test method is used to determine the interlaminar energy release rate G of composite materials [3].

In the following the testing process is described. The sample is joined along a distance of 100 mm. One end of the sample is not joined. At the open end, both materials are dispersed by applying a tensile force F until a delamination length of 100 mm is reached. Therefore, the samples are clamped into a tensile testing machine, Zwick / Roell Z2.5. During the dispersion of the materials the applied tensile force F and the moved distance d of the clamps for the crack growth are recorded. The sample dimensions for the determination of the energy release rate G are shown in figure 2.

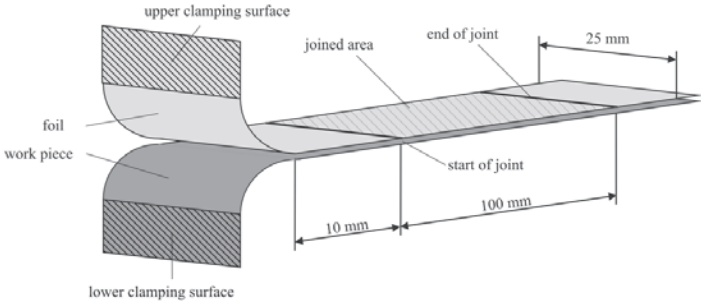

Figure 2. Sample dimension for the interlaminar energy release rate G

The energy release rate G can be calculated by the equation (1) according to DIN EN 6033:

$$G=\frac{A}{a.w}.10^{6} \tag{1}$$

with:

G: interlaminar energy release rate [J/m²]
A: energy needed to achieve the crack growth [J]
a: crack growth [mm]
w: sample width [mm]

The calculation of the interlaminar energy release rate G enables the direct comparison of the produced samples. For the calculation according to equation (1) three values are necessary. The sample width w is defined by DIN EN 6033 to 25 mm. Furthermore, the crack growth a needs to be at least 100 mm and is determined after the test procedure by linear measurement. Consequently, the energy needed to achieve the crack growth A is the most important value to be measured. A direct measurement of the energy is not possible by the tensile testing. However, the energy A can be calculated by the integration of the area below the stress-strain-curve. Therefore, main focus lies on the determination of this area.

3. RESULTS AND DISCUSSION

Due to the special punctual joining technique at the nodes of the joints, the produced sewed joints show unique peaks on the stress-strain-curve along their joints. The corresponding peaks in the seam strength to the stitch length l_{stitch} are shown in figure 3 schematically.

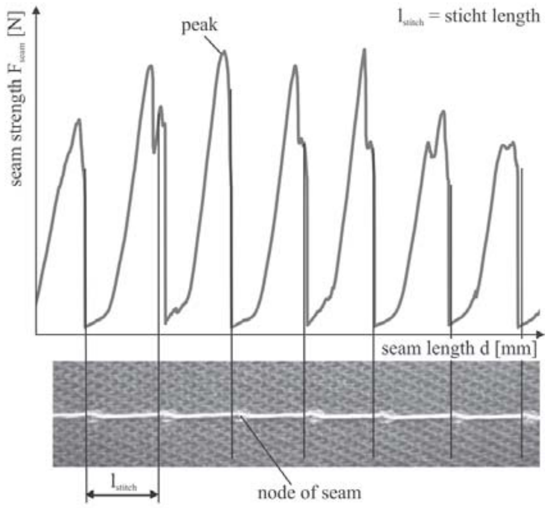

Figure 3. Peaks in the measured tensile seam strength F_{seam}

These peaks correspond exactly with the stitch length l_{stitch} of the seam. Therefore, the node of the seam is the main factor for the seam strength. To calculate the mathematical factor A of the curve (energy needed to achieve the crack growth) an excel based analysing tool has been programmed.

In figure 4 the comparison of the maximal seam strength F_{max} and the real interlaminar energy release rate G is shown. Energy is applied to the seam during the rising slope of the curve. No energy is applied onto the seam by the falling slope. The calculation results in the energy release rate $G_{calculated}$.

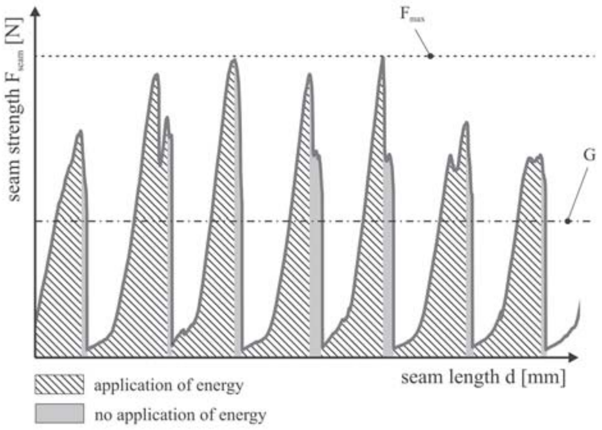

Figure 4. Comparison of the maximal seam strength F_{max} and the real interlaminar energy release rate G

The testing of the adhesive bonded samples showed no peaks along their stress-strain-curves. Therefore the area below the stress-strain curve could be determined using standard analysing tools.

In figure 5 all results for the interlaminar energy release rate G of the sewed samples are shown. The slope of each curve is a value for the influence of one of the four factors (work piece, sewing thread, stitch length l_{stitch} and needle size) on the energy release rate G. The steeper the curve, the higher is the influence of the factor. The shown values relates to the means of all values for one factor.

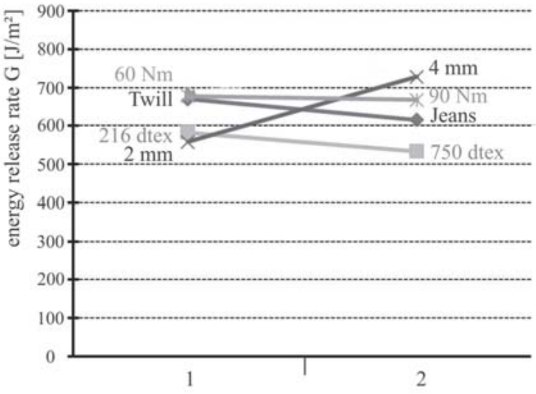

Figure 5. Analysis of the factors for sewing samples

It can be seen in figure 5 that the stitch length l_{stitch} has got the highest influence on the energy release rate G. The sewing thread possesses only a small influence on the energy release rate G. The work piece has got a similar small influence on the joint strength. According to the slope for the needle size it can be stated that the needle has no significant influence on the seam strength.

Furthermore, it was observed that the seam break is caused by the failure of the foil material itself. The material breaks instead of the seam. Therefore, this joining technique fulfils the criteria to achieve high joint strengths.

In figure 6 all results for the interlaminar energy release rate G of the adhesive bonded samples are shown. The determinations of the slopes were calculated in the same way as the slope for the sewing samples.

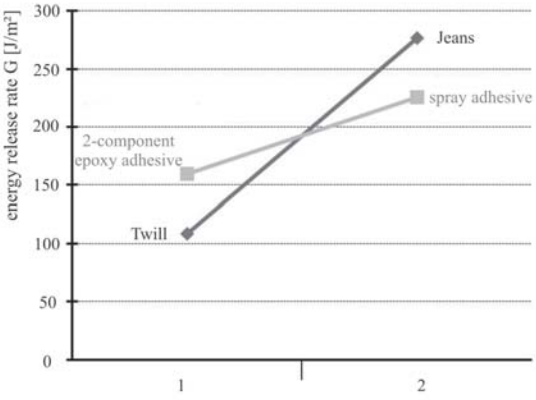

Figure 6. Analysis of the factors for adhesive bonded samples

It can be stated that the work piece has a significant high influence on the joint strength – in contrast to the sewed samples. In addition the adhesive has a high influence as well. In contrast to the sewed samples the adhesive bonding breaks. The foil material as well as the work piece are not influenced by the breakage. The foil is still intact after the experiment.

4. CONCLUSIONS

The analysis of the results indicates that sewing with a long stitch length l_{stitch} has the highest energy release rate G and hence the highest strength. Consequently, the stitch length l_{stitch} is the most important factor regarding the seam strength. Other parameters, e.g. properties of the textile used or the needle size, have only little impact on the strength. The adhesive bonding displayed a much lower strength than the sewing. Furthermore, with this technology the functionality of the OPV-foil is not influenced by the joining techniques. An overview of all results is given in figure 7.

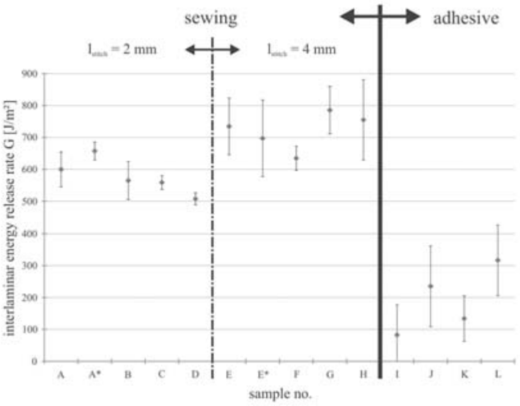

Figure 7. Overview of the measured interlaminar energy release rates

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