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RESEARCH ARTICLE

Adding a Polymer Film Barrier Layer in the Press Forming Process of Paperboard Trays

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ABSTRACT

The aim of this paper was to investigate the possibility to add a barrier layer in the press forming phase of paperboard trays by sealing a polymer film to a paperboard substrate. Plastic coating is often an important part of packages manufactured for food packaging. Traditionally the paperboards for food packaging are coated in the paper mill before the actual forming of the package. Experiments with coated and uncoated boards were made and the bonding and adhesion of materials was observed. The results indicate that adhesion between the board and the film can be achieved in the forming process. However there are challenges, such as lack of adhesion, air bubble formation and deformation of formed products. It is still shown that it is possible to achieve a bond between the paperboard and a barrier film, and to subsequently add a barrier layer from a separate film to paperboard trays in the forming process.

KEY WORDS

barrier, paperboard, forming, packaging, sealing

1.0 INTRODUCTION

The continuously growing packaging market, changing consumer habits worldwide [1] and demands for a greater utilization of sustainable packaging materials require new barrier materials with good convertability for food products such as bakery goods, microwavable instant meals and fast food. Fiber-based packaging materials coated with plastics such as polyethylene (PE) or polyethylene terephthalate (PET) by extrusion and surface treatment with fluorocarbon chemicals have been shown to possess good functionality for many applications. The plastic coatings provide the needed barrier properties against water, grease and oxygen which are needed in food packaging [2].

Press forming is commonly used to form three-dimensional shapes from paperboard [3-5]. In food packaging, the trays are commonly manufactured from either extrusion- or dispersion coated paperboard [4], where the coating has been done in the paper mill. In press forming the trays are usually manufactured from pre-cut and die cut blanks which is pressed into shape between forming tools [3-5].

Coating of the board is normally done by laminating or coating the material using extrusion- or dispersion coating before die cutting and forming. Previous investigations regarding the three-dimensional forming of fibre-based materials have been done with uncoated boards [9, 10], extrusion and dispersion coated boards [3-6] and for wood plastic composites (WPC) [11]. The addition of barrier layer in the forming stage has not been previously investigated. Adding a barrier layer to uncoated board in the forming stage would be advantageous in several ways. First, the base material could be the same regardless of application and the barrier material could be changed according to the needs provided by the packed product. Secondly, the barrier material would not need to withstand the forces in the creasing phase, which is essential to the manufacturing and can sometimes cause cracks or pinholes in the coating [3, 6]. This is especially true for bio-based coatings, which often possess worse mechanical and barrier properties compared to oil-based polymer coatings [12, 13].

The object of this paper was to investigate the possibility to add a barrier layer in the press forming phase of paperboard trays by sealing a polymer film to a paperboard substrate.

2.0 MATERIALS AND METHODS

The board material used in the experiments was Stora Enso (Imatra, Finland) Trayforma Natura with a grammage of 350 g/m^2. The board consisted of a top and bottom layer from sulphate pulp and a middle layer of sulphate pulp combined with chemi-thermomechanical pulp(CTMP). Also an extrusion-coated version of a similar board with 15 g/m^2 of PE (Performa Natura PE) was used to investigate differences in adhesion between the coated and uncoated boards.

The coating films were provided by Südpack (Germany). Two films were used. The first film was Multifol GVA 90 which is a coextruded high barrier multilayer film with a structure consisting of polyamide (PA) / polyethylene (PE) / ethylene vinyl alcohol (EVOH) / PE. The thickness of the film is 90 µm. The second film was Multifol SV 100 with a structure of polypropylene (PP) / EVOH / PE, which is a PE-sealable skin film with a thickness of 100 µm.

The adhesion tests were performed using press forming equipment. The press forming process is shown in Figure 1.

The first test series was done by inserting flat test pieces on top of each other and pressing them together between the moulds for 2s. The size of the board test piece was 120 x 70 mm and the film test piece 96 x 56 mm. In addition to the board and film test pieces a thin paper was inserted between the male mould and the

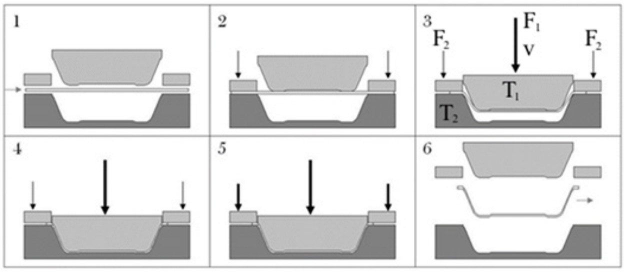

Figure 1. The press forming process [7].

Phase 1: *The paperboard blank is positioned between the moulding tools.*

Phase 2: *The blank holding force tightens the blank between the blank holder (rim tool) and the female tool.*

Phase 3: *The male tool presses the blank into the mould cavity in the heated female tool. The folding of the tray corners is controlled with blank holding force.*

Phase 4: *The male tool is held at the bottom end of the stroke for a set time (0.5 to 1.0 s). If the tray is coated, he plastic coating softens, and creases in the corners of the tray are sealed together.*

Phase 5: *The flange of the tray is flattened by the blank holder.*

Phase 6: *The formed tray is removed, and a new blank can be fed into the tray press. The tray achieves its final rigidity when it cools down.*

plastic film to prevent sticking to the forming moulds in case the polymer film melted. The test setup can be seen in Figure 2. The female tool was heated while the male tool was at room temperature. The temperature of the female tool was varied between 100 and 160°C. The used pressing force was 100 kN. In this test series the blank holding force (F2, Figure 1) did not have an effect in the process since the blanks were only pressed between the female and male tools. In this test series the main focus was in investigating the adhesion between the board and film when subjected to pressure. Examples of test pieces from the first test series can be seen in Figure 3.

The second test series was done using actual tray blanks which were inserted between the tools with barrier film shaped according to the tray blanks inserted on top of the board material between the male mould and the paperboard blank. This test series represented the actual press forming process in which the barrier layer would be added in actual production runs. The size of the tray blank was 285 mm x 198 mm and it was pre-creased with a typical creasing pattern which can be seen in Figure 4. The used parameters were dwell time 2s, pressing force 100 kN, female mould temperature 100 – 180 °C and blank holding force 1.16 kN.

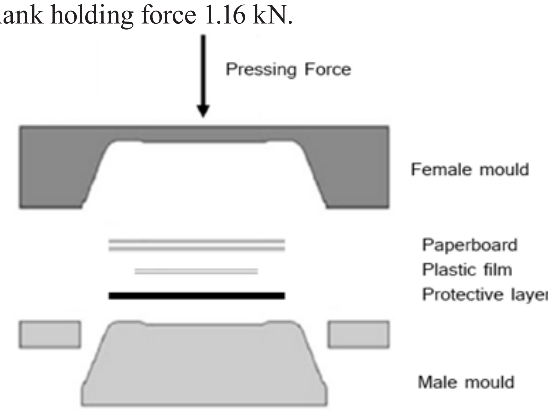

Figure 2. The test configuration for the first test series.

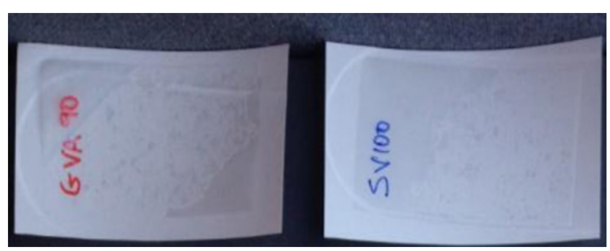

Figure 3. Examples of test pieces (First test series).

The analysis was done by evaluating the adhesion and bonding of the test pieces. The samples were compared to each other on a scale from 0 to 5, where 5 was considered as excellent bonding and 0 as no bonding at all.

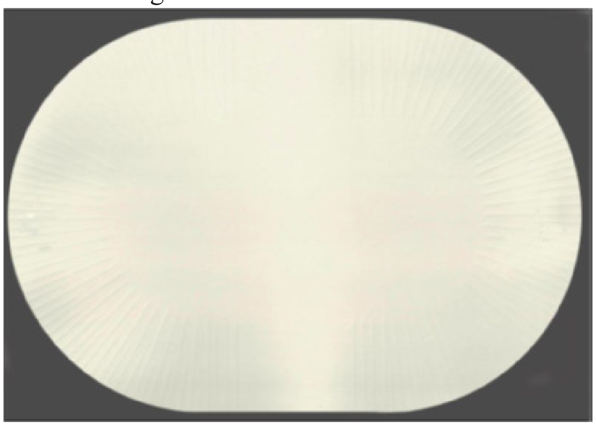

Figure 4. The tray blank geometry used in the press forming experiments (Second test series).

3.0 RESULTS AND DISCUSSION

The results for the bonding and adhesion quality grading are presented in Table 1.

Table 1: Bonding and adhesion test results. The samples were compared to each other on a scale from 0 to 5, where 5 was considered as excellent bonding and 0 as no bonding at all.

Temperature [°C]	Performa Natura PE		Trayforma Natura	
	Multifol SV 100	Multifol GVA 90	Multifol SV 100	Multifol GVA 90
100	1	1	0	0
110	2	2	0	1
120	3	2	1	1
130	3	2	2	2
140	4	3	3	3
150	5	3	3	4

It can be seen from the results that the adhesion properties were better at higher temperatures, and the PE-coated material had better bonding. This is assumed to be caused by the better bonding of polymers since the polymer layers in each material form bonds that cause the better adhesion. However the advantage of adding a barrier layer in the forming stage is questionable, if the board is already coated in the board manufacturing mill.

It must be noted that with the uncoated board (Trayforma Natura) the adhesion in higher temperatures was still very good which suggests that polymer bonding is happening with the board material. The adhesion could possibly be improved by adding certain fillers to the board, since wood fibres are not the most optimal material for the polymers in the barrier film to generate a bond. Possible fillers could include polymer based pigments, such as polystyrene or urea-formaldehyde derivates which are already used in paper and board manufacturing to improve opacity and printing properties [8].

Adding the barrier layer in the press forming process (the second test series) was successful. However, there were some challenges. The main defect observed during the experiments was air bubble formation. Due to the gap between the film and paperboard air is left between the materials and air bubbles are generated. The formation of bubbles decreased slightly when the temperature was increased, but avoiding the bubbles completely was not possible. An example of such air bubble formation can be seen in Figure 5. A possibility to avoid the bubble formation could be air suction holes in

Figure 5. Air bubble formation in a press formed tray, coated with Multifol SV 100 film.

the forming moulds to allow a more rapid release of air from the forming cavity.

When the two films were compared, there were some differences in the bubble formation. SV 100 tended to have more air bubble formation compared to GVA 90. The exact reasons behind this phenomenon were not found. A tray with GVA 90 film added

Figure 6. A tray formed with the GVA 90 film in the press forming process.

in the forming process is shown in Figure 6.

Even though increasing the temperature means less air bubble formation and better adhesion, it does not come without problems. It was observed that with higher temperatures the formed trays started to curl which resulted in shape deformations. This kind of deformation takes place when the film is overheated and can cause the plastic film to deform and to shrink which will curl the paperboard. An example of such deformation is shown in Figure 7.

Figure 7. A deformed tray due to a high temperature (160 °C).

Another observation was the lack of adhesion at the edge of the trays due to low heating which occurred at temperatures under 150 °C. The adhesion was improved when the temperature was elevated up to 180 °C, but this could lead the trays to deform. This could be resulted by uneven heat distribution on the surface of the female mould, or more likely the combination of the uncoated board and the film. This could be possibly avoided by adding additives to the board as described above, to enhance the adhesion properties at lower temperatures.

There are naturally other things to take into account when the barrier layer is added in the forming process, such as the more difficult control of the process. However these experiments show that it could be possible to achieve a viable solution utilising these results. There are several interesting topics for further research, such as testing with different board materials to achieve a better adhesion between the materials and the use of a heated male mould to more effectively bring heat to the sealing layer of the film. Also the further testing of coated trays for pinholes and other defects, and a more exact examination of bonding between the substrates are an area of interest.

4.0 CONCLUSIONS

The results show that it is possible to achieve a bond between the paperboard and a barrier film, and to subsequently add a barrier layer from a separate film to paperboard trays in the forming process. However there are still some challenges such as achieving a good bond to uncoated board, and the formation of air bubbles between the board and the film in the forming process. Adding additives to the paperboard could result in improvement in the adhesion between the board and the film, while the improvement of forming tools could decrease the formation of air bubbles in the forming process.

Because temperature is one of the main factors in the adhesion of the materials, it is recommended that both forming moulds would be heated to achieve a more uniform heating result in lower temperatures and to avoid curling of the formed trays, which was observed at higher temperatures.

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