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THERMAL PROPERTIES OF CARDBOARD LAMINATED WITH POLYPROPYLENE FILM

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The Abstract. The purpose of this study is to determine the thermal properties of cardboard laminated with PP film using an EVA copolymer adhesive solution. The results of the thermal analysis showed that the industrial laminating film and the laminating film obtained in this work based on PP and PEVA exhibit similar characteristics.

The polymer film intended for hot lamination must possess high thermal properties. Differential thermal analysis of the film and paper provides information not only about their thermal characteristics but also about possible interactions between components during laminate formation.

The purpose of this study is to determine the thermal properties of cardboard laminated with polypropylene (PP) film using an EVA copolymer adhesive solution.

For lamination, glossy paper with a surface density of 220 g/m² was selected.
The laminating film used was a biaxially oriented polypropylene (PP) film with a thickness of 20 microns, obtained from LLC JV "Sirdaryo Mega Lyuks" (Uzbekistan).

To bond the PP film with the cardboard, a solution of polyethylene-vinyl acetate (PEVA), a copolymer of ethylene and vinyl acetate, was used. Xylene containing toluene admixtures served as the solvent.

As an analogue, a PP polymer film with an adhesive layer was selected for lamination of paper, with a thickness of 24 microns, manufactured by EKO Film Manufacture Co. Ltd (Guangdong, China).

The thermal properties of the samples were studied using thermogravimetric analysis (TGA) and differential thermal analysis (DTA) methods. The studies were carried out on a Netzsch Simultaneous Analyzer 409 PG (Germany) device equipped with a K-type thermocouple and aluminum crucibles. All measurements were performed in an inert nitrogen atmosphere within a temperature range of 0–600 °C, at a heating rate of 10 K/min.

The DTA method provides information not only about thermal properties but also about the processes involved in the modification of composites. TGA and DTA curves were obtained for the PP film, polymer adhesive, and laminating films with adhesive layers.

Figure 1 presents the TGA and DTA curves of the initial components of the laminated cardboard, and the values of the extremum points and thermal effects are given in Table 1.

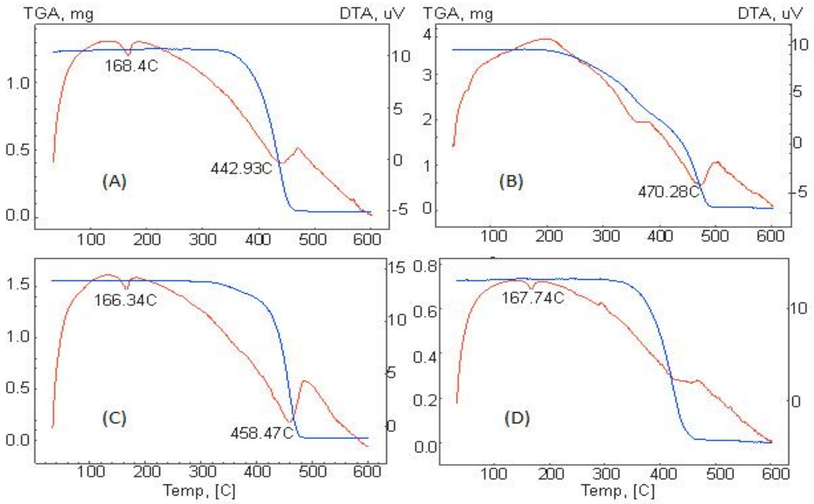

Fig. 1. TGA and DTA curves of polypropylene film (A), PEVA adhesive (B), industrial laminate analogue (S), and experimental laminate (D)

As can be seen from Figure 1 and Table 1, the PP film possesses sufficiently high thermal stability, losing only 0.33% of its mass in the temperature range from 33 to 342 °C. In this interval, the DTA curve shows a single endothermic peak at 168 °C with an effect value of –103.2 J/g, which corresponds to a phase transition — the melting process.

At temperatures above 342 °C, intensive mass loss begins, and by 469 °C, 96% of the sample's mass is lost. In this range, complete degradation of PP occurs, characterized by a peak at 443 °C with an endothermic effect of –952 J/g. The char residue accounts for 2.7% of the initial sample mass.

Table 1

Extreme points of TGA and DTA processes for PP film, adhesive, and laminates

Process Points	**TGA**			**Process Points**	**DTT**	
PEVA Adhesive						
Start, °C	33.49	200.88	492.44	Start, °C	380.62	
End, °C	200.88	492.44	601.71	Peak, °C	470.28	
Mass loss, %	-0.341	-97.472	-0.823	End, °C	496.53	
	-98.636			Thermal effect, Dj/g	-317.32	
Industrial Laminate Analogue						
Start, °C	32.47	321.43	481.52	Start, °C	139.15	373.59

End, °C	321.43	481.52	601.72	Peak, °C	166.34	458.47
Mass loss, %	-1.289	-96.778	-0.709	End, °C	179.30	484.79
	-98.776			Thermal effect, Dj/g	-65.38	-937.49
Experimental Laminate						
Start, °C	31.87	325.20	466.53	Start, °C	146.23	
End, °C	325.20	466.53	601.71	Peak, °C	167.74	
Mass loss, %	-0.959	-97.26	-1.918	End, °C	183.1	
	-99.19			Thermal effect, Dj/g	-100.12	

The TGA curve of the PEVA adhesive consists of three regions: from 33–201 °C, a negligible mass loss of 0.34%; from 201–492 °C, a significant mass loss of 97.47%; and from 492–602 °C, another slight mass loss of 0.82%. The char residue of the sample amounts to 1.3% of the initial mass. The melting of PEVA occurs at 80–85 °C without any mass loss, accompanied by a slight endothermic effect. On the DTA curve, a single peak with an endothermic thermal effect of –317.3 J/g was observed at 470 °C, corresponding to the complete degradation of the sample. It was established that above 85 °C, PEVA transitions into a viscous-flow state and remains thermally stable up to 200 °C.

The TGA and DTA curves of both the industrial laminate analogue and the experimental laminate exhibit a similar shape to those described above. In the first region of the DTA curve, the industrial laminate loses 1.29% of its mass up to 321 °C, while the experimental laminate loses 0.96% up to 325 °C. In the second region, both samples undergo complete degradation: the analogue loses 96.78% of its mass in the range of 321–482 °C, and the experimental sample loses 97.26% in the range of 325–467 °C.

Distinct endothermic peaks corresponding to the melting process are observed on the DTA curves of both samples at 166–167 °C. In the industrial laminate sample, a second endothermic peak appears at 458 °C with a thermal effect of –937.5 J/g. In the experimental sample, this peak is slightly smoothed, probably due to the penetration of the adhesive solution into the molecular-surface structure of the PP film.

The results of the thermal analysis showed that the industrial laminating film imported from China and the laminating film obtained in this study based on PP and PEVA exhibit similar properties. The results also made it possible to determine the optimal temperature for forming laminated cardboard.

The high thermal stability and melting temperature of polypropylene, along with the relatively low melting point of the ethylene–vinyl acetate copolymer, allow the thermal lamination of paper and cardboard to be carried out at 90–100 °C. Under these conditions, the adhesive solution ensures high adhesive strength between the film and the cardboard (6.6 N), resistance to multiple double folds (more than 120 cycles), and good wear resistance (5.12 kPa·m²/g).

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