Measurements of PVC composite with Corn Cob flour additive

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Abstract— *Mechanical and thermo-analytical analysis carried out on the composites. In order to determine the relationships between structure and properties of composite, it is necessary to carry out different measurements. The tests were: tensile test, hardness test, thermal conductivity SEM, DSC and DMA. The results showed that the mixtures were inhomogeneous. The tensile and hardness test resulted that the composite has stronger structure and an increase in the strength values. From the thermo-analytical analysis the corn cob additive effect in the composite structure can be observed. The result of the DMA shows that the additive works as inactive filler, and does not change the glass transition temperature of the rigid PVC foam.*

Keywords— Composite, PVC, foam, DSC, DMA.

I. INTRODUCTION

Due to continuous development and in order to fulfill the needs of customers the production of polymer composites are becoming highly common [1]. In construction PVC composites are met [2]. PVC is a hardly degradable bulk plastic; with the use of natural additives this ability can be changed. The production of composites propose many advantages such as higher strength and aesthetic [3]. Also many disadvantages rise like weak impact strength due to weak adhesion and water uptake [4]. During PVC composite foaming the corn cob additive differs the structure of the foam highly. Foam structure also differs based on the density of the composite and the presence of additives [5]. In this paper the mechanical and structural abilities of the resulting foam structure is to be determined.

II. MATERIALS

The raw material was the PVC powder. The PVC power's K values are 58 from the BorsodChem Zrt. Company. The mixture contains stabilizers, lubricants, processing aids, foaming agent (azodicarbonamide), filler and corn cob nature filler. The commercial corn cob fillers are grinded and dried (24hour-80 °C). The additives main components are 42% cellulose, 46% hemicelluloses, 7% lignin and 5% organic substances. The average particle sizes are approximately 492 μm. The PVC-corn cob ratio was 100/20 phr in the mixtures.

The composites were made / homogenized in a high-speed mixer at 110°C. During the mixing method the composite should be a homogenous system. After the mixing process, a twin-screw laboratory extruder was used to make the foaming sheets. The extruder parameters were: D=30mm, L/D= 20, compression rate 1:3 and the extruder temperature set at 165°C/170°C/170°C°/175°C/175°C/180°C from hopper to die. The extruded sheets were used for the different examinations. The specimens were cut by pneumatic punching tools.

TABLE 1
DENSITY VALUES OF PVC-CORN COB COMPOSITE

Material	Density [g/cm^3]
PVC-Corn cob composite	1.1252±0.006

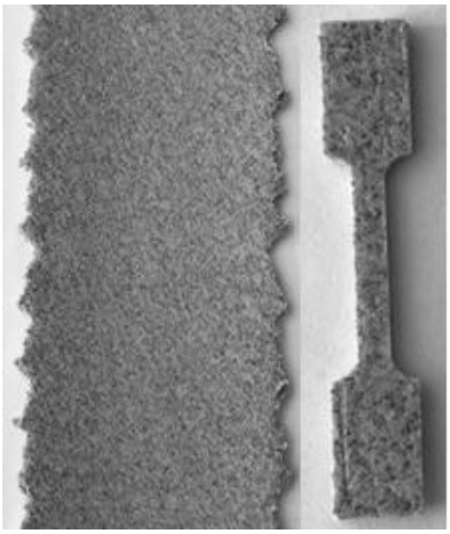

FIG 1. FOAMING SHEET AND THE SAMPLE FOR MECHANICAL (TENSILE) TEST

III. METHODS

3.1 Tensile test

The tensile test was performed by INSTRON 5566 device, according to ASTM D638-10 standard. The stress-strain behavior during the measurement was examined. The test's speed was 100 mm/min.

3.2 Hardness test

The hardness test was made by at Zwich/Roell Shore D equipment. Shore D punching tool was used for harder materials or composites. The test was performed according to standard ISO 868. The values (Table 3) were calculated as the average of 20 point on the specimen.

3.3 Thermal Conductivity test

The conductivity measurements were made by at C-Therm Conductivity Analyzer. The device is able to examine liquids, solids, and foam and etc. material properties. The technique is characterizing the thermal conductivity and effusion of the materials.

3.4 Scanning Electron Microscopy

The structure of the foaming sheets can be determined with Scanning Electron Microscope. The shape and the size can be determined with microscope. The test was measured by ZEISS equipment. The samples have to be made of conductive material; this is a thin conductive layer. The type of the layer was gold.

3.5 Dynamic Mechanical Analysis

The DMA analyze is a thermo-analytic method to determine elastic behavior. The load is applied in a periodically alternating in time manner, other than that everything is observed with the changing of temperature. During the analysis the applied temperature range, the glass transition temperature, rigidity, the efficiency of the softener and the structure of polymer mixtures can be determined also.

3.6 Differential Scanning Calorimetric

The DSC method monitors the heat transitions in the material which are mainly caused by chemical reactions. The DSC measures the electrical capacity needed to maintain the same temperature in the sample and the reference sample. During the measurement the crystallic transitions, the phase transitions and even the purity of the material can be defined.

IV. RESULTS

A number of tests were performed on specimens. These were: tensile test, hardness test, C-Therm, SEM, DMA and DSC analysis.

4.1 Tensile test

The Table 2 shows the results of average of 7 pcs sample.

TABLE 2
THE EFFECTS OF CORN COB FILLER ON THE TENSILE STRESS-STAIN VALUES

Material	Maximum Tensile Stress [MPa]	Maximum tensile stain [%]
Without corn cob	15.04±2.4	6.12±1.01
PVC-Corn cob composite	25.83±0.46	6.59±0.77

Generally, the results of measurement reflected the corn cob modifier effect. The result proves this modification; the mechanical strength increased. The stress-strain values show that the stress values increased, but the strain did not change to the properties of the original rigid PVC.

4.2 Hardness test

TABLE 3
HARDNESS TEST DATA

Material	Mean
Without corn cob	39.76±0.32
PVC-Corn cob composite	66.14±1

The hardness value tightly correlated with the result of SEM analysis. The values of hardness and density affected the foaming process.

4.3 Thermal Conductivity test

TABLE 4
THERMAL CONDUCTIVITY DATA OF THE COMPOSITE

Material	Conductivity [W/mK]
Without corn cob	0.090±0
PVC-Corn cob composite	0.090±0

The commercial PVC foams thermal conductivity value is in a range between to 0.03-0.07. The original rigid PVC foam and the composite conductivity values were the same from the Table 4. Based on the results, the values can be classified into the extruded sheet and the extruded foaming sheet.

4.4 SEM analysis

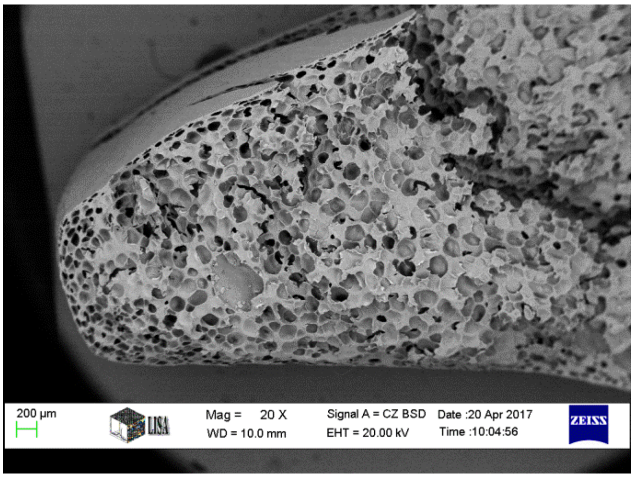

FIG 2. SCANNING ELECTRON MICROSCOPE FRACTURED STRUCTURE OF RIGID PVC FOAM

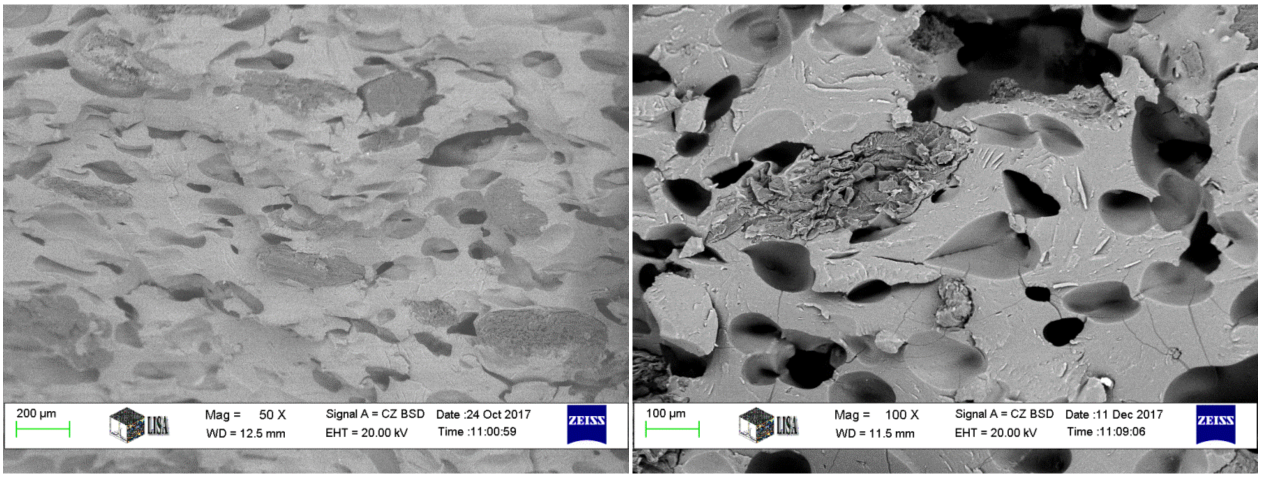

FIG 3. SCANNING ELECTRON MICROGRAPHS OF FRACTURED SURFACES OF PVC – CORN COB COMPOSITE; 50 x (left) and 100x (right)

The results of microscopy show the formation and structural deformations of the cells. The Fig 2. illustrated that the bowling agent works well; the morphology formed to open celled structured. The Fig 3. shows the fractured surfaces of the composites. We can see that the cells did not create due to the corn cob additives. Compact structure has formed.

4.5 DMA analysis

Fig 4. illustrated the glass transition temperature (Tg) and maximum tan δ. It was found that the glass transition temperature of PVC did not change because of the corn cob additives. The original PVCs glass transition was 83 °C.

From the result of DMA test the glass transition temperature of PVC is 90.48 °C. The glass transition temperature of original rigid PVC foam was 89.3 °C. Based on these result the corn cob did not change the characteristics of the main structure. It works as filler in the PVC system. It has no other effect in the internal structure properties.

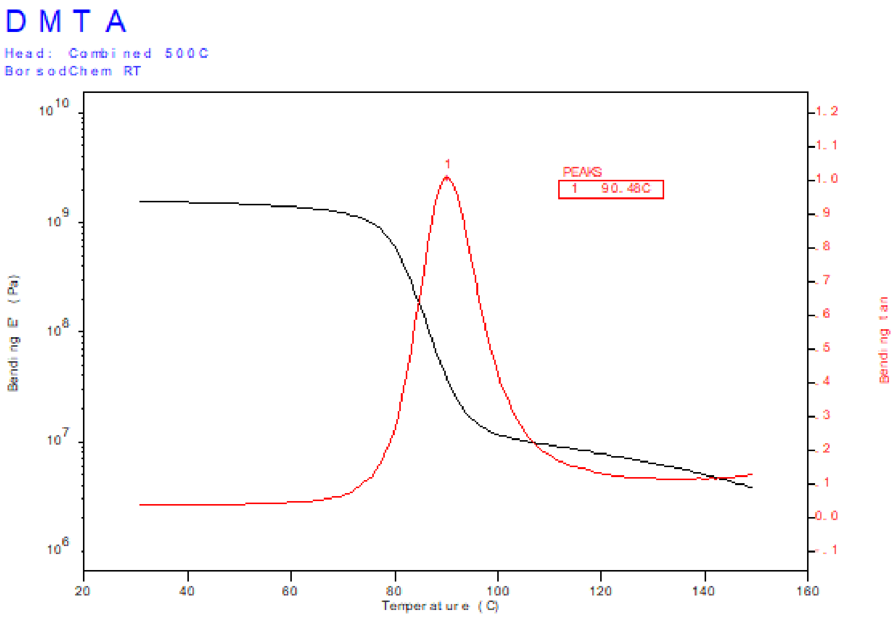

FIG 4. DMA RESULTS: PVC - CORN COB FORMULATION

4.6 DSC analysis

Based on the test results, we can conclude and predict the materials thermal processing history. The Fig 5. shows the actual production temperature (196 °C) and the level of processing. The processing temperature was increased from the die setting temperature. Apparently, the PVC super molecule was not completely processed. This 85% of processing was excellent regarding the materials properties.

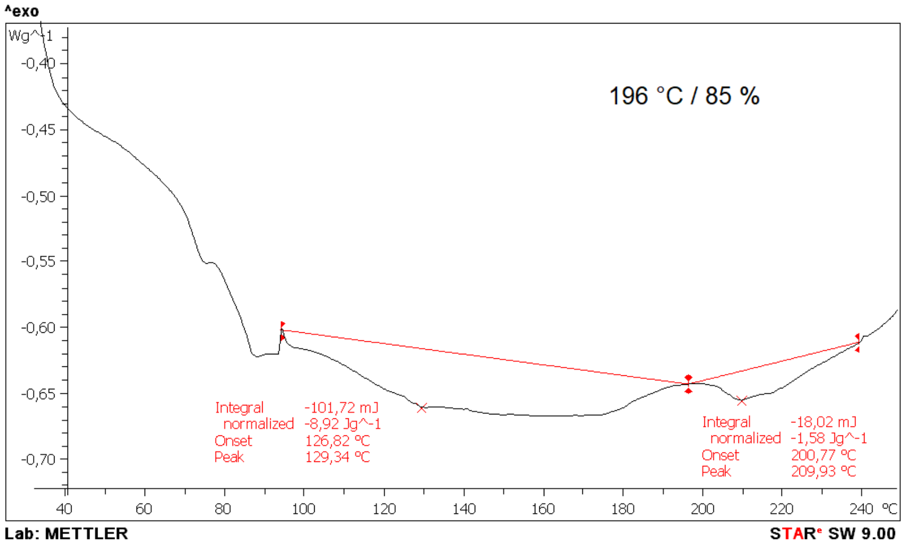

FIG 5. DSC RESULT: PVC - CORN COB COMPOSITE

V. CONCLUSION

The PVC-Corn cob composites were made successfully. The mechanical- and thermo analytical properties of the composites were improved with corn cob.

(1) The corn cob flour modified the PVCs main properties.
(2) The fillers were dispersed unequally in the rigid PVC.
(3) The reinforcement effects were appreciable; the tensile strength values were higher.
(4) The size and shape of the cells depend on the density and the filler's sizes.
(5) Corn cob additives work as an inactive filler, and does not changes the glass transition of composite.
(6) On the result of the DSC analysis the highest processing temperature of the composite can be observed. The processing of PVCs super molecular structure was carried out in 85%.

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