Investigation of used Conveyor Belts by the Differential Scanning Calorimetry Analysis

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Abstract: **In this paper is presented the use of differential scanning calorimetry analysis of the used conveyor belts. This method has been specifically tested on the individual components contained in the used conveyor belts esp. rubber pellets, cord and fabric. The result of the analysis is the determination of Tg temperature and melting temperatures (Tm) by the components.Weanalyzed used conveyor belts and after this analysis it was determined components and their application to the industry.**

Keywords: **Differential scanning calorimetry, analysis, used conveyor belts.**

1. Introduction

If the observed physical property difference of heat flows in the sample and reference substance, we speak about differential scanning calorimetry(shortly DSC).

According to DSC calorimeters structures are divided into two types, namely calorimeters power and heat flux calorimeter [1]. Application range DSC calorimeter is usually indicated for temperatures ranging from -180 °C to +500 °C. The upper temperature limit determined by radiation heat loss is proportional to the square of the fourth absolute temperature and heat loss due to radiation above the upper limit of the measured signal [7].

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DSC method is suitable for the measurement of the characteristic temperatures of phase transitions I and II.,the type and the quantification of the enthalpy associated to the physical characteristics of the chemical transformations in condensed matter systems. It may further be used to measure the heat capacity. The determination of the material purity shows kinetics reactions [2]. In this method, samples were run on a linear heating rate of the sample heat flow, which is proportional to the specific heat immediately. Inside the housing of resistivity, which is normally maintained at room temperature (cca.20°C) are located in two symmetrical containers. Resistance thermometer and the heating member embedded in the carrier serve as a primary sample temperature control system. The secondary temperature control system measures the temperature difference between the two carriers and the difference provides for the control of heat flux from zero, which is measured. Otherwise, it can be said that the temperature of the sample is kept isothermally with a comparative sample (or block) supplying heat to the comparative samples. The amount needed to maintain isothermal conditionswith respect to time and temperature. [2], [5],[6]. We are used small sample (milligram quantities) which are arranged on the metal film, it reduces the temperature differential to a minimum. A small heat capacity of the system allows using a heating rate (ten $K.min^{-1}$, $°C.min^{-1}$) and ensuring a large resolving power. The amount of heat released is therefore proportional to the amount of the electrical energy consumed to heat the samples. [3], [5], [10], [11].

2. Experimental procedure

The characteristic feature of all DSC measuring systems in the twin type design is the direct in–difference connection of the two measuring systems which are of the same kind.[3], [6]. It is the decisive advantage of the difference principle that, in first

approximation, disturbances, such as temperature variations in the environment of the measuring system affect the two measuring systems in the same way and are compensated when the difference between individual signals is formed. The working range of DSC for polymeric materials [8], [9] is usually indicated by temperatures ranging from -180 °C to +500 °C. Beside the decomposition of most organic substances the upper temperature limit is determined by the radiation heat loss which is proportional to the fourth square of absolute temperature. DSC method is suitable for the determination of the characteristic temperatures of phase transitions as well as the quantitative determination of associated phase transition enthalpies connected with the physical and chemical transformations in condensed matter systems. In this method, the sample is subjected to a linear heating rate and heat flux in the sample, which is proportional to prompt a specific heat. Inside the experimental apparatus, which is normally maintained at room temperature (about 20°C) are set two symmetric containers. During a predefined temperature program the temperature of the sample is kept isothermally with a comparative sample (or block) by the supply of heat to the comparative sample [8].The amount of electrical energy needed to maintain isothermal conditions is recorded as a function of time or temperature. Used small samples („mg"quantities) that are placed on metal sheets reduce the thermal gradient to a minimum. The small heat capacity of the system allows the use of large heating rates ($K.min^{-1}$) and provides a great distinctive character [2],[3],[6].

Input materials and measuring process:

- DSC 204 NETZSCH (Germany)
- Software-The NETZSCH Proteus
- Sample containers from Al (approx. 5 mm)
- Sample of used conveyor belts[6].

The following table (Table 1.) presents a measurement of the parameters. Mass of the test sample is 8.6 mg. The temperature is in the range of -50 °C to 300 ° C.Test starts first cooling a sample to -180 ° C, followed by heating. When the heating temperature reaches 50 °C, the measurement starts. Subsequently, the sample is subjected to the heating value of 300 ° C.

Table 1.Parameters of measurement

Characteristics of measurement	Value
Weight of specimen	8,6 mg
Start-temperature	- 50 °C
End-temperature	+300 °C
Laboratory temperature	20,5 °C
Humidity	50%
Standard	ISO 113 57

After a defined time, the measurement analysis is completed. The program NETZSCH Proteus evaluated data which was obtained during the measurement process. The time demand of the analysis of one sample was nearly 2 hours. During this analysis the time-enthalpy curves cover the glass transition temperature Tg and the melting point Tm of the material. Figure1. shows the sample room inside the equipment 204 DSC NETZSCH (Germany). The sample is located on the right-hand side. The reference is placed on the left-hand side.

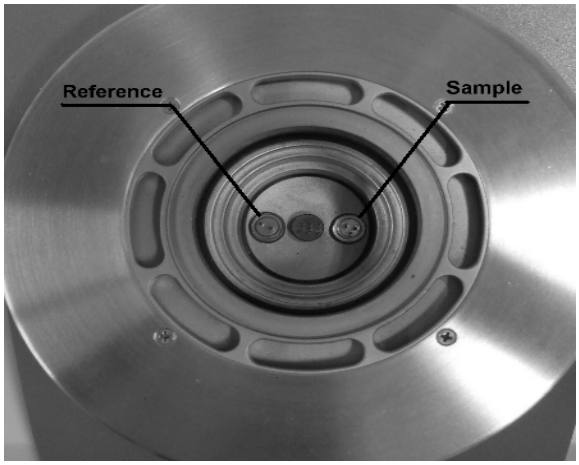

Figure 1. The sample stored in the equipment DSC 204 NETZSCH[6]

Figure 2.The Equipment DSC 204 NETZSCH [6].

After running the specified time-temperature program the measurement was completed. NETZSCH Proteus-software was then used to analyse the data obtained during the measurements. Figures3.-6. are a graphical presentation of DSC. Line A shows the first run of analyzed fabrics. An enthalpy consuming process – we assumed an evaporation - in the first run was observed at 73,3 °C. The graph clearly shows two well separated melting processes. The Melting temperature as the maximum of the first peak is 218,1 °C and the second peak occursat 255,5 °C.The Red curve displayed first heating by fibres analysis. The glass transition temperature Tg of 1.heating (Figure 1.) has a value of 73.3 ° C. The melting peak of the first „peak 1 " is 218.1 ° C at the top of the second " peak 2 " 255.5 ° C . [5], [12].

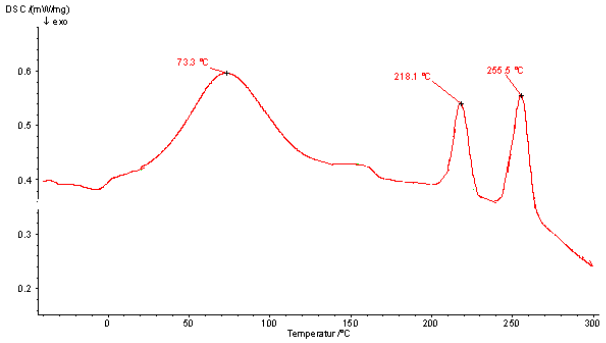

Figure 3. Differential scanning calorimetry of 1st heating

Figure 4. is shown in black 2. heating fibres component. The values of the graph are as follows, in the first of the peak corresponding to a temperature of 215 ° C, the second peak has a value of 252.8 ° C.

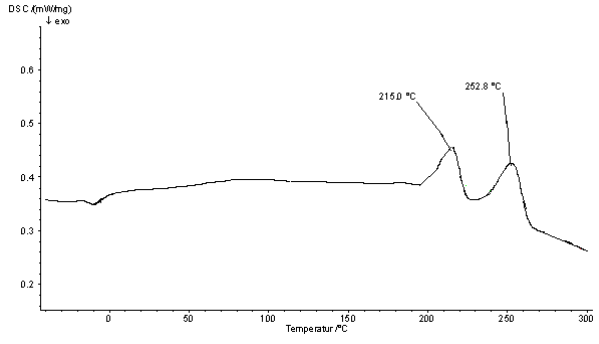

Figure 4.Differential scanning calorimetry of 2nd heating

Figure 5. describes a rubber component, from the conveyor belts. The Tg is 89.6 ° C

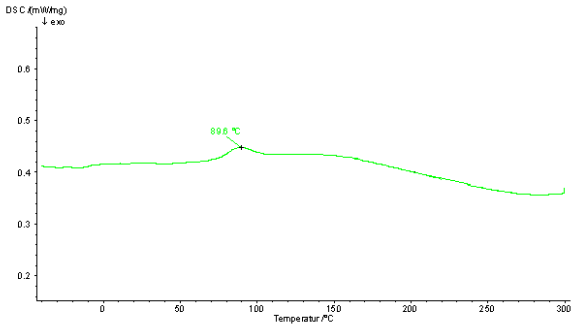

Figure 5. Differential scanning calorimetry of rubber particle

The graph (Figure 6.) shows that the glass transition temperature of the fabric has a value of 73.3 °C, the rubber component of 89.6 ° C. The melting points of the textile component are from 218.1 °C to 255.5 °C. The difference between the first and the second heating does not show significant differences in the temperatures of the individual components. This proves that our measurements were conducted in order. [1],[3],[5] The graph shows that the sample of the two curves of PA, means 1 and 2 heating (red curve-first heating, black curve- 2nd heating). The first and the second heating arecarried out due to deviations arising between the test sample and the instrument. In the first case, in the graph is seen the value of 73.33 ° C, meaning that the sample was present in a water or alcohol, it is also possible that in the sample is residual solvent. The values of 218.1 °C and 255.5 °C represent the sample point Tm. Two peaks are the result of the material made of two materials, PA6 and PA6.6, in minimum quantity is located polyethylene terephthalate (PET). By the second heating it was stable graph with values of 215.0 °C and 252.8 °C. [2], [4], [5].

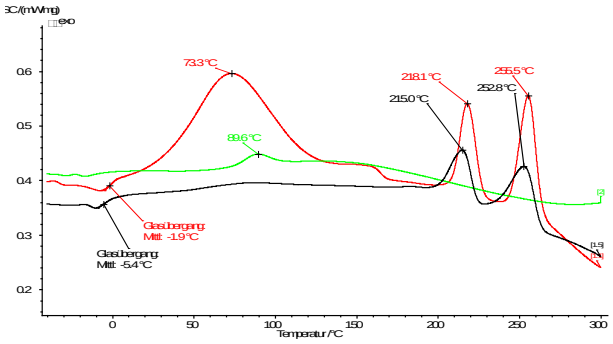

Figure 6. Differential scanning calorimetry of fibres and rubber particle

Legend:

From german language „Glasuebergangstemperatur"- Glass transition temperature (Tg)
Red curve- Fibres (1st heating)
Black curve- Fibres (2nd heating)
Green curve- Rubber particle

The difference between the first and the second heating means anomaly between the sample and the sensor, e.g. uneven „slump" test sample into an aluminium can , in the second case we get a definite crystallinity of samples and analysis of the material as such . [1], [4], [6] is also provided better grip and sample containers. The value of 89.6 ° C in the rubber component is the melting or evaporation of the sample, it is seen from the graph; it is a rubber material of high strength. By further analysis we have found that the composition of the textile cord is made up of crystalline cellulose. [3], [4].

3. Conclusion and future direction of the research

The paper aimed to bring the use of differential scanning calorimetry for the analysis of the components of used tyres. From the course of the analysis we came to the following conclusions. The glass transition temperature of the rubber component has a value 89.6 °C. From the analysis it was found that the fabric is formed by min. two different types of polyamide. Through Literature "Praxis der thermischen Analyse von Kunststoffen „ (from german language) it was determined that the value of 216 °C corresponds polyamide PA6 (based on a comparison to TM- melting points). The value of 252 ° C represents a polyamide PA 6.6.

The difference between the first and the second run – the vanishing peak at 73,3 °C - cold be attributed to the presence of residue solvent such aswater or ethanol in the industrial material, which is evaporated during the first run.The peaks at approximately 215 °C and 255 °C remain nearly unchanged and representing melting of the sample at Tm. The two peaks are result of the fact that the material consists obviously of at least two different substances – we attribute the lower Tm to polyamide PA 6 and the higher one to PA 6.6 [1]. But also polyester (PET) fibers are known to melt on 250 °C point. Further investigations such asinfrared spectroscopy are necessary for a clear attribution.

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