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DILATOMETRY AS A TOOL FOR DETERMINATION OF THERMAL EXPANSION

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ABSTRACT: Dilatometry is standard method for determination of structure changes of material subjected to thermal heating. By using the dilatometry measurements is one able to measure some characteristic properties as linear coefficient of thermal expansion, volume coefficient of thermal expansion, glass transition temperature and others. All these material constants can be determined from temperature dependence of elongation or volume expansivity. These constants are very important for determination of material behaviour subjected to thermal heating or cooling. In this paper we have determined linear coefficient of thermal expansion for polyurethane sample. Measurements were made on dilatometer 402 PC from Netzsch Instruments.

KEY WORDS: dilatometry, linear coefficient of thermal expansion, coefficient of thermal expansivity

1. INTRODUCTION

In the work [1], authors deal with determination of coefficient of thermal expansion of rigid polyurethane reinforced with hammer milled glass fibre. In the article [2], authors deal with determination of linear coefficient of thermal expansion of some polymer materials. Authors in the work [3] study polymer nanocomposites with low positive thermal expansion coefficient.

We have dealt with determination of linear thermal expansion coefficient of polyurethane sample.

2. THEORETICAL BACKGROUND

According to German norm DIN 51005, dilatometry is a technique in which the dimension of a substance under negligible load is measured as a function of temperature while the substance is subjected to a controlled temperature program.

When the sample is subjected to thermal program, its length is changing. Let the sample's initial length at temperature T_0 be l_0. Let the sample's final temperature be T. Then her length l at this temperature can be calculated by using equation (1)

$$l = l_0(1 + \alpha(T - T_0)) \qquad (1)$$

where: α - linear coefficient of thermal expansion
Linear coefficient of thermal expansion α can be calculated from equation (2)

$$\alpha = \frac{1}{l_0}\left(\frac{dL}{dT}\right) \qquad (2)$$

where: dL - infinitely small change of a length
dT - infinitely small change of a temperature
l_0 - initial length of a sample

Directly from equation (2) one can see, that with increasing length in dilatometry test materials have positive coefficient α and with decreasing length they have negative coefficient α.

3. EXPERIMENT

3.1 Measuring apparatus

The measurements were done on dilatometer 402 PC from NETZSCH instruments. Measuring apparatus is shown on Fig. 1.

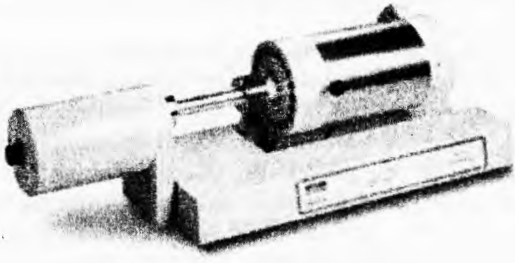

Fig. 1: Measuring apparatus

3.2 Measuring Procedure

1. Cubic sample of polyurethane is located in a sample carrier and subjected to negligible load by pushrod.
2. After setting the relative length of sample to zero, parameters of measurement program are set. These parameters include initial length, pushrod material, Start temperature, End temperature and heating rate.
3. After the measurement is started, sample is subjected to temperature program and temperature is measured by sample thermocouple. Change in length is measured by LVDT technique.
4. At the end of measurement the measured signals of temperature and extension can be transferred to evaluate program, in which linear coefficient of thermal expansion can be calculated. The measured data can also be exported as text documents in ASCII format. The data in ASCII format can be processed in Matlab 7.0, which was used in our case.

4. RESULTS

Four measurements of a sample under same temperature program were made. Temperature program starts at temperature of 20 °C and ends at temperature of 80 °C. Heating rate was 4 $K.min^{-1}$. Table 1 shows geometrical parameters of the sample.

Tab. 1: Geometrical parameters of sample

	Diameter (mm)	Length (mm)
sample	10	18

Fig. 2 shows calibrated temperature dependence of relative length. Fig. 3 displays calibrated temperature dependence of linear coefficient of thermal expansion of the sample.

Computed value of linear coefficient of thermal expansion for the polyurethane sample was $\alpha = (9.078 \pm 0.282).10^{-5}\ K^{-1}$.

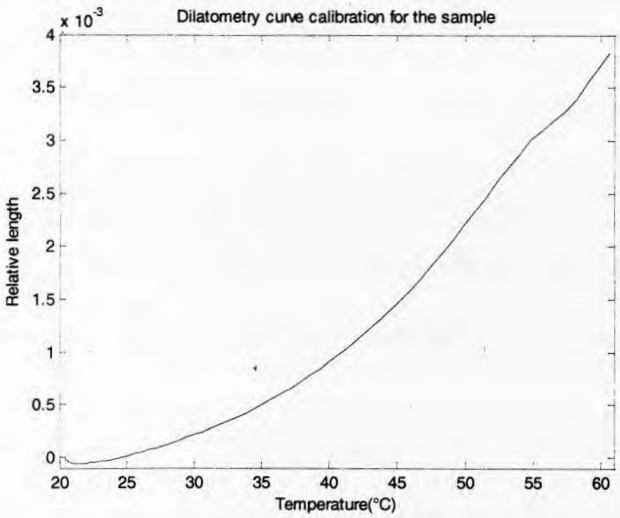

Fig. 2: Calibrated dilatometry curve of polyurethane sample

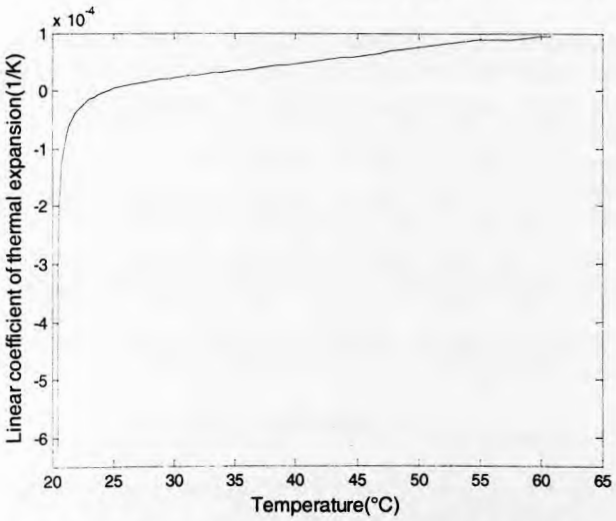

Fig. 3: Temperature dependence of coefficient α of polyurethane sample

Figure 4 shows temperature dependence of relative length of standard sample Al_2O_3. In figure 5 we display temperature dependence of coefficient of linear expansion. Computed value of linear coefficient of thermal expansion for the Al_2O_3 sample was $\alpha = (4.651 \pm 0.001).10^{-7}\ K^{-1}$.

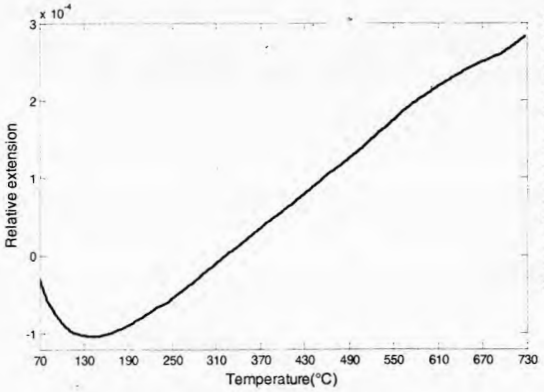

Fig. 4: Temperature dependence of relative extension for Al_2O_3

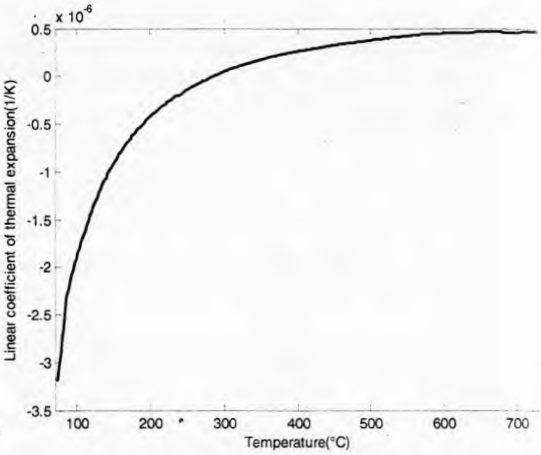

Fig. 5: Temperature dependence of coefficient α for Al_2O_3

5. CONCLUSIONS

From presented figures is clearly seen, that relative length of a sample can be characterized by linear coefficient of thermal expansion only after the temperature of 55 °C.

Computed coefficient of thermal expansion is positive – sample's length rises with the increase of a temperature.

Computed coefficient of thermal expansion is close to 10^{-4} K^{-1}. Order of coefficient is (-4) – same as for rubber blends and most of polymeric materials. This order was obtained from experimental measurements of rubber blends, rubber blend with carbon nanotubes, most of used rubbers, sample of Al_2O_3 and this sample.

Temperature measured by sample thermocouple is lower than the end temperature in the furnace. The reason for this is that sample doesn't transfer all the heat given to it – low thermal conductivity.

Dilatometry is a technique proper for determination of dimensions' changes and in polymeric materials it is also proper for determination of characteristic temperatures. In this case, the temperature of 55 °C is probably glass transition temperature of used material. .

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6. REFERENCES

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